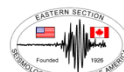


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CGU_B_01: Biogenic greenhouse gas exchange in agricultural landscapes

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N₂O emissions as affected by nutrient and water table management in South Western Ontario

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The concentration of N₂O gas has increased by 20% since preindustrial era mainly due to excessively high fertilizer applications over the recent decades. The objective of this four-year study (2012-2015) was to analyse N₂O emissions as a function of water table management and source of applied fertilizers for corn and soybean crop rotation in southwestern Ontario. The treatments of the field study were regular tile drainage (DR) and controlled drainage with sub-irrigation (CDS), each combined with inorganic fertilizer (IF) and solid cattle manure (SCM). Gas sampling was conducted using a non-steady state closed chamber method and analyzed for N₂O emissions. Fluxes were calculated using the HMR model (Pederson et al., 2010). The N₂O emissions were higher following fertilizer applications, precipitation, irrigation and spring tillage. N₂O emissions were significantly affected by the two fertilizer treatments from 2012 to 2014, with lower emissions from SCM than IF plots. However, in 2015, the emissions were more affected by water management, with lower emissions from CDS than DR plots. Due to the slow release of SCM, N₂O emissions carried over to the following years when fertilizers were not applied. The treatment of CDS combined with SCM emitted 45% lower N₂O than DR combined with IF, which are traditional practices of the farmers in the region. Our results suggest that use of SCM combined with controlled drainage at 46 cm water table can significantly reduce N₂O emissions in South Western Ontario.

Preferred Platform: Oral Presentation

Student Presenter: Y

Comparison of Soil Emission Measurement Techniques in the Agriculture Landscape: Gas Chromatography, WS-CRDS, FTIR and NDIR Sensor Based Approaches

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Determination of greenhouse gas (GHG) emissions, such as carbon dioxide, nitrous oxide, and methane from agricultural fields is essential for understanding the environmental impacts of intensive crop and livestock production systems. Various techniques exist to quantify gas concentrations in air samples, including gas chromatography, spectral analysis and isotopic fractionation methods. However, repeated sampling, in time, of air from stationary chambers (1 m²) is a laborious process and constrains our ability to assess GHG fluxes at the spatio-temporal scale needed to describe the variability present in farm-scale production areas, which span hectares. Simultaneous in situ measurement of GHG fluxes at multiple locations across agricultural production areas is an attractive alternative. The use of commercially available automated chambers connected via tubes to stationary gas analyzers is limited by high instrumentation and analytical costs. Therefore, a wireless sensor network (WSN) approach for in situ measurement using low-cost sensor node assemblies was developed as a cost-effective means to assess spatially variable soil carbon dioxide fluxes across agricultural fields. This WSN uses Non-Dispersive Infrared (NDIR) sensors for gas measurement which limit concentration analysis to certain gases and can be subject to interference by the presence of other gases and external factors such as pressure and humidity. This report presents a case study where CO₂ fluxes from agricultural soils under various environmental conditions were quantified with the NDIR WSN and compared to several other techniques, including gas chromatography, Isotopic Wavelength-Scanned Cavity Ring-Down Spectroscopy (WS-CRDS) and Fourier-Transform Infrared (FTIR) gas analysis.

Preferred Platform: Oral Presentation

Student Presenter: Y

How the integration of farm productivity information changes our perception of greenhouse gas emissions from the dairy industry

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Environment and Climate Change Canada prepares Canada's national inventory of agricultural greenhouse gas emissions (GHG), including biogenic CH₄ and N₂O emissions from livestock production. Dairy livestock emissions have been calculated using temporally fixed parameters; however, Canada's dairy industry has undergone an intensification that has resulted in a 45% increase in milk production since 1990, changes in management and feed causing subsequent changes to the GHG emission profile of the industry and, as a consequence, strategies to reduce emissions. To better capture changes in the industry over time, a dairy nutrition time series was compiled and methane conversion rate (Y_m) values were calculated using published predictive methane equations. Further, a time series of manure management practices was developed from the Farm Management Surveys. Finally, country-specific N loss factors were developed to better quantify N losses during manure storage, manure application and deposition on pasture, range and paddock (PRP). Total emissions were reduced by 1 MtCO₂e in 1990 and 75 ktCO₂e in 2015. Enteric fermentation emissions decreased by 11% to 14%. The use of liquid manure systems increased from 17% in 1990 to 64% resulting in a 100% increase in the CH₄ emission factor, and a 27% decrease in the N₂O emission factor; however, N₂O was also offset by a 16% increase in N excretion. A greater amount of N was applied to soils, increasing soil N₂O emissions by 38 to 78%, and PRP by approximately 15%. Total N losses decreased by over 50%, except for leaching of N applications, which increased proportionally to N excretion. In summary, significant changes to emission trends have occurred since 1990 and the identification of these trends allows a more informed approach to mitigation, as well as the ability to capture the impacts of mitigation efforts going forward.

Preferred Platform: Oral Presentation

Student Presenter: N

Ebullition fluxes in shallow agricultural reservoirs

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Freshwater systems are important sites for biogeochemical transformation. Often overshadowed by larger systems, small lentic systems—especially those in agricultural contributing areas—may exhibit notable greenhouse gas emissions, but this has not been well quantified. In particular, ebullition can be an important pathway for methane release to the atmosphere but is rarely measured. We investigated ebullition fluxes in small constructed reservoirs implemented as a beneficial management practice in agriculturally-dominated southern Manitoba. These reservoirs demonstrate significant nutrient retention, ultimately improving downstream water quality; however, associated sedimentation promotes anoxic conditions in benthic zones of these reservoirs—a hotspot for the biological production of methane. In this contribution we will quantify ebullition fluxes for eight agricultural reservoirs, and investigate whether sediment properties are linked to ebullition rates. In addition, we will describe spatial variability in ebullition flux within reservoirs, contrasting littoral zones with pelagic measurements provided by a novel automated sensor. An enhanced understanding of ebullition in these systems will enhance the capacity to quantify atmospheric greenhouse gas fluxes from aquatic systems receiving water from agricultural lands.

Preferred Platform: Oral Presentation

Student Presenter: Y

Pulse Crop / Wheat Rotations: Greenhouse gas emissions originating from above- and below-ground residues

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Nitrous oxide (N₂O) and carbon dioxide (CO₂) exchanges between soils and the atmosphere have drawn much attention for their important role in global warming. Yet, there is considerable uncertainty regarding the contribution of crop residues to N₂O and CO₂ budgets. A field experiment at the University of Saskatchewan's Goodale Research Farm near Saskatoon, SK, Canada, was established from 2014 to 2018 to determine the relative contributions of above-ground residue (AGR), below-ground residue (BGR), and fertilizer N to N₂O and CO₂ emissions in a subsequent wheat crop. The experiment involved dual-isotope (¹⁵N and ¹³C) labeling AGR and BGR of chickpea, faba bean, lentil, and pea and measuring soil emissions during the pulse crop phase, through the spring thaw period in the year after the pulse crops were grown, over the spring wheat growing season and through the spring-thaw period after the wheat crop was grown. Two separate experiments were run, one in 2014 to spring 2016, and the second in 2016 to the spring of 2018. The pulse crops were labelled with ¹³CO₂ and ¹⁵N-urea during the 2014 and 2016 growing seasons. After harvest, AGR from enriched and non-enriched plots were swapped such that ¹⁵N/¹³C-AGR and ¹⁵N/¹³C-BGR were located in separate plots. ¹⁵N₂O and ¹³CO₂ were measured weekly basis using manually-sampled, non-steady state chambers, gas chromatography, and Picarro isotopic ¹⁵N₂O and ¹³CO₂ analysers. During the wheat year N₂O emissions from AGR were approximately 4.5-times lower than emissions from BGR. Residue derived emissions were lowest for chickpea and highest for lentil. Peak ¹⁵N₂O emissions associated with application of urea fertilizer were generally 3- to 4-times greater than the peak emissions associated with the crop residues. In contrast, CO₂ emissions were approximately 3-times greater from AGR than BGR with wheat grown on pea residue emitting the lowest amounts of CO₂.

Preferred Platform: Oral Presentation

Student Presenter: no

Bicarbonates in irrigation water contribute CO₂ to the soil surface efflux: a stable isotope study

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Irrigation of crops is essential to meet growing demands for food and is set to increase in the future. In Canada alone water-use rose by 22% between 2014 and 2016, to over 2 billion m³.yr⁻¹. Irrigation water can contain dissolved bicarbonates, which liberate CO₂ when applied to soils. However, little is known about the volume of CO₂ released or whether this C flux is important for climate change models. Differences in the ¹³C content of soil surface CO₂ efflux and bicarbonates dissolved in irrigation water provide an opportunity to trace CO₂ sources released during irrigation. We present work from 2 experiments using high frequency, continuous stable isotope analysis in a drip irrigated apple orchard using bicarbonate-containing irrigation water drawn from Okanagan Lake, BC. First, we quantified CO₂ released over 1h from dry and wet soils after irrigation with 60 cm³ of deionized or lake water. Second, we quantified CO₂ released over 3h after applying operational volumes of lake water (1 L) to bare soils and soils covered with woody mulch. In Expt. 1, the surface efflux of dry soils responded rapidly; deionised water led to mineralization of labile soil C and a decline in the ¹³C content of soil surface efflux, whereas lake water led to a marked increase in ¹³C content due to dissolved bicarbonates. In Expt. 2, the presence or absence of woody mulch had no effect on the volume of bicarbonate-derived CO₂ released from lake water; the ¹³C content of the surface efflux increased substantially from the start of irrigation. Using isotopic mass balance we estimated that 12.5% of the soil surface efflux was caused by bicarbonates in the lake water. Across this region, 5.7 million m³ of Okanagan Lake water are used annually for irrigation; this amounts to 25 million L CO₂ .yr⁻¹. In conclusion, the inorganic C content of irrigation water generates significant volumes of CO₂, and accurate global C cycling predictions require a better understanding of this C source.

Preferred Platform: Oral Presentation

Student Presenter: No

Do the effects of dietary greenhouse gas inhibitors persist in beef cattle manure during composting and stockpiling?

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Dietary supplements 3-nitrooxypropanol and monensin may reduce methane production in ruminants. There has been little research into whether the effects of these inhibitors persist in manure. If they affect manure composition or remain biologically active, they may alter greenhouse gas emissions (GHG; i.e., CO₂, CH₄, N₂O) and NH₃ from manure. Furthermore, emission responses may vary depending on manure management practices. The objectives of this research were to test whether manure from beef cattle receiving 3-nitrooxypropanol or monensin in their diets had lower GHG emissions than that from control cattle that did not receive these additives. Emissions were also assessed in manure that was composted or stockpiled in the semi-arid climate of southern Alberta. Manure was obtained from beef cattle fed a typical barley grain-based finishing diet with no additives (control), 3-nitrooxypropanol (200 mg kg⁻¹ DM) alone, or 3-nitrooxypropanol (200 mg kg⁻¹ DM) and monensin (33 mg kg⁻¹ DM). Manure was combined within treatments and randomly assigned to either three replicate compost windrows or stockpiles. Compost was turned once a month for the first three months of the trial, and for the following four months, both the compost and stockpile were left in storage. Methane, CO₂, N₂O and NH₃ fluxes were measured once or twice a week for three months, and once a month thereafter. Carbon dioxide, CH₄ and NH₃ emissions were lower from the stockpile than from compost, with no difference in N₂O emissions between storage methods. The results showed no persistent effects of 3-nitrooxypropanol or monensin on CH₄, CO₂, N₂O and NH₃ emissions from manure. These results suggest the inhibitory effects of 3-nitrooxypropanol and monensin occur only in the rumen, and do not persist in manure.

Preferred Platform: Oral Presentation

Student Presenter: N

Conservation tillage fertilized with manures increased N₂O emissions from a silty clay but not a sandy loam soil under a cool temperate environment

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While it is generally understood that conservation tillage in heavy soils under a cool, wet climate increases N₂O fluxes compared with inversion tillage, the interaction between tillage and manure type on soil N₂O fluxes in different textured soils is not well understood. To investigate how long-term applications of different manures interact with tillage effects on N₂O fluxes, we established a long-term trial in 2009 in eastern Canada, using two tillage (conventional: inversion at 25 cm in autumn; conservation: harrow at 5 cm in spring) and three fertilizer types (liquid swine manure, liquid dairy manure and a 0-N control) arranged in a split-plot design with 3 replications. The experiment is reproduced on two contrasting soil textures (silty clay and sandy loam) located approximately 400m apart in a wheat-maize-soybean rotation. During 2016 (wheat) and 2017 (maize), we estimated the N₂O fluxes from each plot using standard non-flow through, non-steady state, manual chambers for the snow-free period (1 April through 30 November). Cumulative fluxes for the snow free periods ranged from 0.6 kg N₂O-N ha⁻¹ for the control/inversion tillage to 7.6 kg N₂O-N ha⁻¹ for the cattle manure/conservation tillage. Conservation tillage increased soil N₂O fluxes for both manure types and the 0-N control in the clay soil (mean flux for all fertilizer treatments over both seasons were 5.5 and 2.4 kg N₂O-N ha⁻¹ season⁻¹ for the conservation and inversion tillage, respectively); while on the sandy loam the N₂O flux was similar between the conservation and inversion tillage systems (mean flux for all fertilizer treatments over both seasons were 1.4 kg N₂O-N ha⁻¹ season⁻¹ for both the conservation and inversion tillage). Considering that soil organic C may not increase in fine-textured soils under conservation tillage in temperate, humid areas such as eastern Canada, our findings suggest that conservation tillage in the region may lead to a net decrease in the GHG balance.

Preferred Platform: Oral Presentation

Student Presenter: N

Development of Two-Dimensional Models Correlating N loading and Soil Clay Content for Calculations of Emission Factors

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Conversion efficiency of N fertilizers applied to agricultural soils to N₂O is commonly evaluated using an emission factor (EF; N-g emitted (N-g applied)⁻¹). The Intergovernmental Panel on Climate Change (IPCC) has a default Tier 1 EF of 0.01 (1%) for N₂O emissions from agricultural soils following the application of organic fertilizers, such as livestockmanure, compost, sewage sludge and digestates. However, some investigations have shown the EFs vary greatly, depending on regional factors, as well as organic fertilizer type, soil type and application method. In this study, two-dimensional models, including linear, exponential and hyperbola responses, correlating N loading and soil clay content for calculations of emissions and EFs were developed. The developed two-dimensional linear model were applied to N₂O emissions from the three UK farms inputted by digestate and slurry. The squares of correlation coefficients of the observed and linear modeled emissions were 0.998 and 0.999 for digestate and slurry, respectively, and the corresponding squares of correlation coefficients of EFs were 0.998 and 0.938. The two-dimensional linear model also predicted that the EFs increased linearly with decreasing clay contents and the maximum EFs for digestate and slurry were 0.95 and 0.76%, respectively.

Preferred Platform: Oral Presentation

Student Presenter: YES

Closing the gap between fall and spring nitrogen applications to reduce nitrous oxide emissions with enhanced efficiency fertilizers in Manitoba

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Fall applications of synthetic nitrogen (N) fertilizers to cropland can result in nitrous oxide (N₂O) emissions during spring-thaw. Thus, spring N applications are recommended to mitigate N₂O losses. Enhanced efficiency N fertilizers (EEF) are also recommended to reduce N₂O losses. The objective of this study was to compare N₂O emissions of EEF and non-EEF sources, and application timing, fall and spring, in southern Manitoba. Using the static-vented chamber technique, both late-fall and spring applications of urea and anhydrous ammonia (AA) using urease inhibitor, nitrification inhibitor, and controlled release EEF sources were examined in two replicated plot trials in each of three years from 2015 to 2017. Fall N sources were applied at soil temperatures below 10°C and spring N sources applied at seeding. Urea N sources were applied mid-row banded and AA knifed in. Nitrogen rates were similar for all treatments at a trial based on fall N test and yield goal of hard red spring wheat (variety AAC Brandon). Amongst urea sources, eNtrench, SuperU and ESN had lower cumulative N₂O emissions compared to urea in at least 1 of 6 sites. Urease inhibitor, LIMUS, and nitrification inhibitor, N-Serve, did not significantly lower cumulative N₂O emissions for urea and AA, respectively. An N source effect was measured in 4 of 6 sites and amongst those 4 sites applying eNtrench and SuperU reduced emissions by 55 and 43%, respectively, compared to urea alone. Combining eNtrench, SuperU and ESN sources, fall applied cumulative N₂O emissions were similar to spring at 4 of 6 sites. No timing effect was measured between AA sources. Grain protein from spring N sources was significantly greater than fall. No N source or timing effects was observed from grain yield measurements. In conclusion, some EEF sources can reduce N₂O emissions with late-fall application while some in general, can reduce N₂O emissions regardless of application timing from applied urea.

Preferred Platform: Oral Presentation

Student Presenter: Y

A New Automated Chamber System for Assessing N₂O and CO₂ Emissions from Soil Lysimeters

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Diversifying annual crop rotations is a strategy that mimics natural ecosystems and is postulated to increase agricultural resilience to climate change, soil quality, and provision of soil ecosystem services. However, diverse cropping systems could increase soil mineral N levels and lead to greater leaching and/or N₂O emissions. It can be difficult to fully evaluate the interactions between the two N-pollution pathways simultaneously in traditional field studies as drainage is largely unconstrained, and the spurious nature of N₂O emissions requires long-term, continuous measurement. Combining weighing lysimeters with automated soil flux chambers solves this issue by providing a closed system to measure N outputs via drainage and soil emissions. A set of 18 weighing lysimeters were installed in Elora, Ontario, Canada in May 2016, to establish a long-term study of N-leaching and greenhouse gas emission from traditional and diverse cropping rotations for two different soil types. Each lysimeter is equipped with a semi-recirculating automated chamber for continuous measurement of soil N₂O and CO₂ fluxes. The chamber system was designed to operate year-round and configured to measure three chamber fluxes per 20 minute period so that fluxes from each of the 18 lysimeters are measured every 2 hours. Concentrations of N₂O and CO₂ are simultaneously measured at 10 Hz with a tunable diode laser absorption spectrometer (TGA200A, Campbell Scientific Inc.). Extensive laboratory and field tests were used to evaluate the chamber operation and flux calculation methods. Preliminary results clearly show the effect of treatments on soil N₂O emissions from the 1.5 years this system has been in operation. This paper will discuss the design and operation of the chambers and present preliminary results of the flux measurements.

Preferred Platform: Poster Presentation

Student Presenter: N

Can we design forested riparian buffer strips to minimize soil greenhouse gas emissions as affected by earthworms?

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Forested riparian buffer strips (FRBS) are common in agroecosystems of Southern Quebec and Ontario because of their purported ability to sequester nutrients from agricultural runoff. The full environmental benefits of FRBS can only be evaluated, however, by accounting for a wide range of criteria that go beyond stream water quality. For example, it is important to determine the net greenhouse gas (GHG) balance of FRBS relative to adjacent agricultural fields. It is also important to identify the factors controlling these GHG emissions in order to propose optimal FRBS designs that concomitantly provide multiple environmental benefits. One of these factors is the presence of earthworms (EW), which may modify the rates at which CO₂, N₂O and CH₄ are released from soil. We hypothesized that higher humidity and litter carbon inputs, and lower physical disturbance, would cause FRBS to be a refuge for EW in agricultural landscapes. A field survey was conducted, in 2017 and 2018, to quantify EW species abundances in FRBS and adjacent agricultural fields across Southern Quebec and Ontario. At each of 30 sites, we collected and identified EW from three plots and noted the tree species, understory vegetation, drainage class and five soil physicochemical variables (texture, pH, total C, total N and % organic matter). EW abundance was significantly higher in FRBS than in adjacent fields. Redundancy analysis was used to summarise the variation in EW community structure as a function of site characteristics. It was determined that EW abundance was positively correlated with moisture, organic matter, deciduous trees and soil clay content, but negatively correlated with coniferous trees and sand. Microcosm studies are underway to test the isolated and interactive effects of EW life habit (anecic vs. endogeic), soil texture (loam vs. clay) and soil origin (coniferous FRBS vs. deciduous FRBS vs. agricultural field) on GHG emissions.

Preferred Platform: Poster Presentation

Student Presenter: Y

Understanding hotspots and hot moments of greenhouse gas emissions from cultivated Histosols

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Agriculture represents 8% of CO₂, 28% of CH₄, and 71% of N₂O emissions in Canada. While fossil fuel consumption and livestock emissions represent a considerable portion of these CO₂ and CH₄ emissions, agricultural soils generally represent a source of CO₂, a sink for CH₄, and are the primary source of N₂O emitted by the agricultural sector. As the production of these gases is controlled by the soil microbiome and modulated by climatic, edaphic and agronomic factors, it remains difficult to predict farm-level greenhouse gas emissions due to the occurrence of 'hotspots' across fields with identical management practices, along with 'hot moments' of gaseous flux that are triggered by climatic events. This is especially true for cultivated Histosols, which are characterized by sporadic and significant greenhouse gas fluxes. Compared to mineral soils, Histosols are of particular interest because they contain at least 20% organic matter, which is the substrate for microbially-mediated CO₂, CH₄, and N₂O production. The objective of this study was to gain insight into the greenhouse gas emissions from cultivated Histosols in relation to the chemistry and dynamics of their soil organic pools. Through cavity-ring down spectrometry, the isotopic compositions of CO₂ and CH₄ gases will be determined to characterize sources, i.e. physically uncomplexed detritus of recent origin, aggregate-occluded carbon, and mineral associated organic carbon pools. This, in addition to the analysis of N₂O isotopologues permitting the identification of nitrification/denitrification processes, will further elucidate the dynamics of greenhouse gas evolution. With a spatio-temporal sampling framework, we aim to synthesize source data of arable greenhouse gas fluxes with soil biogeochemical characteristics, farm management practices, and climatic factors to understand the manifestation of 'hotspots' and 'hot moments' in cultivated Histosols.

Preferred Platform: Poster Presentation

Student Presenter: Y

Greenhouse gas emissions from a grazed pasture system managed for nutritional content

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A multi-year project has been established to derive field-based measurements of greenhouse gas (GHG) emissions from a grazed pasture system. Cicer milk vetch or sainfoin were seeded into replicated (n=4) alfalfa/brome grass paddocks at a research site near Lanigan, SK. Supplying these low-bloat legumes for grazing cattle increases the palatability and nutritional content of the pasture. Measurements of GHGs emitted from the cattle, along with rumen analyses are being made to investigate how changes to diet affect methane (CH₄) production. Similarly, changes to diet are expected to affect the composition of urine and manure deposited on the pastures. Urine and manure inputs to the soil, together with the change in species composition of the pasture plants are expected to alter GHG emissions and nutrient sequestration potential of the soil system. This poster will describe the approach taken to measuring GHG emissions from the grazed system as a whole.

Preferred Platform: Poster Presentation

Student Presenter: N

Assessment of water use efficiency in selected vegetation coverage at a farm scale in Southern Ontario

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Agricultural lands are one the largest fresh water consumers and have a significant impact on the global carbon cycle. Water use efficiency (WUE) describes the ratio of carbon uptake per water loss in plant ecosystems. WUE is an important factor which can inform us about the carbon and water dynamics within agricultural ecosystems. WUE is mediated through leaf stomatal conductance, which in turn can be affected by many environmental factors such as air temperature, water availability, nutrient availability and photosynthetic light availability. In this study, we calculated WUE of a farmland near Maryhill, Ontario, using a theoretically based photosynthesis model to predict the carbon dioxide (CO₂) and water vapour flux of the growing vegetation. We used air temperature, solar radiation, soil water content and the relative humidity of air, as well as leaf nitrogen content, as model input parameters. Through calculation of stomatal conductance, the model predicted the CO₂ and water vapor flux from the vegetation coverage, which were used to simulate WUE. We calibrated the model for the selected vegetation coverage using observed CO₂ and water vapour fluxes measured by the Eddy Covariance method. Here we present our model results, discussing the sensitivity of simulated WUE to different model input parameters for each vegetation coverage type.

Preferred Platform: Poster Presentation

Student Presenter: N

**Studying the Effects of Freezing Duration and Soil Moisture on Nitrous Oxide Emissions
using a Novel Laboratory Method**

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Freezing and thawing of soils leads to increased emissions of nitrous oxide (N₂O); however, the link between soil freeze-thaw (FT) cycles and N₂O emissions remains poorly understood. Production of N₂O during FT is linked to anaerobic denitrification which, in turn, is strongly influenced by soil temperature, moisture, and availability of carbon (C) and nitrogen (N). While field experiments are essential for demonstrating the importance of FT induced N₂O emissions under real-world conditions, results are often variable due to fluctuating environmental conditions. Laboratory studies are useful for gaining understanding of soil processes because environmental conditions can be controlled. However, simulating field FT conditions in a laboratory setting is challenging and previous laboratory studies targeting N₂O production from soils have been unrealistic (i.e. minimum temperatures, freezing rates, etc.). In this study, target treatments of 1000, 3000 and 5000 freezing degree hours and keeping soil moisture above 25% VWC was simulated in a laboratory environment and the effects of FT on N₂O emissions were evaluated. Significant fluctuations of N₂O emissions and soluble C and N concentrations (within the 0-5 cm layer) were observed over the duration of the experiment relative to controls. For example, in all simulation systems, N₂O emissions were measured when soil within the 0-5 cm layer thawed and stayed above 0°C. When comparing the cumulative emissions of N₂O between treatments, significant differences were found between systems exposed to different amounts of freezing. In general, the greater amount of freezing a system was exposed to, the greater the N₂O emissions. Within the freezing levels, N₂O emissions were greatest in soils that were kept between 25 and 30% VWC compared to control soils. Differences observed between freezing durations, and moisture amendments as well as the developed methodology will be discussed.

Preferred Platform: Poster Presentation

Student Presenter: Y

Measurement of greenhouse gas fluxes from a conventionally managed blueberry field on Westham Island in Delta, BC

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Agricultural soils are a significant source of greenhouse gas (GHG) emissions, including carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O), and may be targeted for mitigation considering future climate change. Few annual estimates of continuous GHG emissions are available in British Columbia (BC) for important cropping systems such as blueberries. Our goal is to measure year-round GHG emissions from a conventionally managed highbush blueberry field in Delta, BC, with the intent to inform models and develop best management practices to reduce emissions. Fluxes of CO₂, N₂O, and CH₄ are measured continuously using eddy covariance (EC) and bi-monthly using static (non-steady state) chambers (SCs). The EC system includes a sonic anemometer (Gill R3-50, Gill Instruments, UK) and two closed-path gas analyzers that measure CO₂/H₂O (LI-7000, LI-COR Inc., NE, USA) and CH₄/N₂O/H₂O (913-1054, Los Gatos Research Inc., CA, USA). Comparison of water vapour flux measurements using both analyzers showed good agreement. SCs are measured manually with a portable CO₂/CH₄/N₂O/H₂O analyzer (DX4040, Gasmeter Technologies, Helsinki, Finland). Controlling meteorological and soil variables are also monitored. SCs used to capture the spatial variability of fluxes in terms of the conventional row/alley blueberry system with raised sawdust beds showed general agreement with EC measurements. Preliminary results between November 2017 and January 2018 indicated that the field was, on average, a weak source of CO₂, N₂O, and CH₄ emitting 1.27 $\mu\text{mol m}^{-2} \text{s}^{-1}$, 1.93 $\text{nmol m}^{-2} \text{s}^{-1}$, and 2.03 $\text{nmol m}^{-2} \text{s}^{-1}$, respectively. The presence of perennial grasses in the blueberry inter-rows appears to significantly reduce winter CO₂ emissions as daytime net ecosystem exchange negatively peaked between -1 to -2 $\mu\text{mol m}^{-2} \text{s}^{-1}$, indicating photosynthetic uptake of CO₂. Further data-processing including stability thresholds, chamber scaling, acceptable wind directions, and footprint analysis will be presented.

Preferred Platform: Poster Presentation

Student Presenter: Y

Pasture systems shape soil microbial populations and resulting greenhouse gas fluxes

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In an effort to decrease enteric methane emissions and increase protein uptake in cattle, producers may introduce cattle to a forage legume diet. However, introducing legumes to pasture systems can affect soil microbial community composition as well as soil nitrogen content, which may in turn affect greenhouse gas (GHG) emissions from soils. Two novel forage legume blends and a grass/alfalfa control were sampled for GHGs as well as soil microbial properties throughout the 2017 growing season. Preliminary PLFA analysis suggests that microbial community structure, rather than simple abundance, affects GHG flux in forage pasture systems. Information about how forage legume pasture systems affect soil microbial carbon and nitrogen cycling will help shape management practices that mitigate GHG emissions. In an effort to decrease enteric methane emissions and increase protein uptake in cattle, producers may introduce cattle to a forage legume diet. However, introducing legumes to pasture systems can affect soil microbial community composition as well as soil nitrogen content, which may in turn affect greenhouse gas (GHG) emissions from soils. Two novel forage legume blends and a grass/alfalfa control were sampled for GHGs as well as soil microbial properties throughout the 2017 growing season. Preliminary PLFA analysis suggests that microbial community structure, rather than simple abundance, affects GHG flux in forage pasture systems. Information about how forage legume pasture systems affect soil microbial carbon and nitrogen cycling will help shape management practices that mitigate GHG emissions.

Preferred Platform: Poster Presentation

Student Presenter: y

Nitrogen: Potential for conversion, consumption and nitrous oxide (N₂O) emission in irrigated Canola (*Brassica napus* L.)

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Canola (*Brassica napus* L.) is an important crop in Western Canada, and its cultivation depends heavily on nitrogen (N) fertilizer application. Nitrous oxide (N₂O) production in soils is due to the response of nitrifier and denitrifier communities to soil management practices; however, baseline information on the response of these microbes in irrigated soil in Western Canada is currently lacking or insufficient. This study investigated the impact of two different rates and timing of N fertilizer application (110 and 220 kg urea-N ha⁻¹) which was either broadcast at seeding or applied as a split rate at seeding and bolting as well as the effect of irrigation. Nitrification and denitrification potential, as well as microbial enzyme activities responsible for key N conversions (urease and arylamidase), and the abundance of genes involved in nitrification and denitrification (*nirS*, *nirK*, *amoA*, *amoB* and *nosZ*) were measured in soils from the two year field experiment. Sampling event, but not rate or timing of N application significantly affected urease and arylamidase enzyme activity. Potential nitrification was affected by the rate as well as timing of N application and irrigation water. The abundance of bacterial ammonia monooxygenase (AOB *amoA*) and nitrous oxide reductase (*nosZ*) genes were affected by fertilizer application rate and timing of application but the strongest influence on gene abundances was sampling event. This result suggests that management practices such as irrigation and application of N fertilizer generally stimulated biological conversions of N fertilizer, while the rate and timing of N application increased potential for nitrification and increased N₂O emission. Relating these conversions to canola yield and gaseous loss as N₂O is underway.

Preferred Platform: Poster Presentation

Student Presenter: Y

Effect of the Application of Biosolids on Nitrate and Ammonium Exposure and Nitrous Oxide Emissions

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Biosolids are the treated organic and nutrient-rich solids of sewage sludge. Mineral and organic nitrogen (N) from biosolids application in the field can result in a considerable amount of nitrous oxide (N₂O) emissions and influence the dynamics of ammonium (NH₄⁺) and nitrate (NO₃⁻) in the soil. In this study, we examined the effect of biosolids application on N₂O emissions and NH₄⁺ and NO₃⁻ concentrations in the soil. Three different types of biosolids: liquid mesophilic anaerobically digested (LMAD), alkaline treated (AT), and composted (CP) was applied with two different methods: incorporation (IN) and surface spreading (SS) in 2017. A positive control (urea) and a negative control (no N) were also considered in this study. N₂O emissions were measured by using static chamber method and NH₄⁺ and NO₃⁻ exposures were measured using ion exchange membranes. N₂O emissions were influenced by biosolid type but there were no significant differences in N₂O emissions between methods of application. The highest emissions (167 N₂O g N/ ha) were reported in LMAD biosolids whereas, AT (80 N₂O g N/ ha) and CP (70 N₂O g N/ ha) were not significantly different from the control. The lower carbon to nitrogen ratio of LMAD as compared to AT and CP promoted N mineralization thus resulting in more mineral N and N₂O emissions. Cumulative N₂O emissions were positively related to NO₃⁻ and NH₄⁺ exposures. LMAD biosolids generated higher NO₃⁻ and NH₄⁺ exposures than AT and CP. The variation in carbon to nitrogen ratio of biosolids controlled the NH₄⁺ and NO₃⁻ dynamics and N₂O emissions at this site. The results can be helpful to regulatory authorities in creating new inventories of N₂O emissions in Canada.

Preferred Platform: Poster Presentation

Student Presenter: N

Greenhouse gasses emissions reduction potentials by riparian plantings in southern Ontario agricultural systems: a case study approach

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The influence of perennial buffer type (trees, shrubs, grasses), age and soil texture in relation to carbon (C) sequestration, and reduction of GHG emissions (CO₂, CH₄ and N₂O), in the terrestrial and aquatic components of RBS is not well understood. In this context, a series of parallel studies were conducted in 2017, within the Grand River watershed, as a part of a federally funded agricultural greenhouse gas project. Grass riparian buffer (GRB), when compared to rehabilitated buffer (RH; deciduous trees: 31 years old), un-disturbed natural forest (UNF) buffer and adjacent (5 m from the buffer) conventional agricultural land (AGL), had significantly ($p < 0.05$) higher average CO₂ emissions up to 683 mg CO₂-C m⁻² h⁻¹. The greatest mean N₂O emissions occurred in AGL, 126.3 mg N₂O-N m⁻² h⁻¹. The UNF had significantly higher CH₄ emissions up to 2033 mg CH₄-C m⁻² h⁻¹, compared to the other land-use types including the AGL. The RH buffer did not significantly emit higher amounts of any G and conversion of N₂O to N₂ gas, was highest in the RH (8.62 Log₁₀ nosZ gene copies g⁻¹ dry soil) and GRB (8.36 Log₁₀ nosZ gene copies g⁻¹ dry soil) sites, suggesting complete denitrification at these sites, and relating to relatively low N₂O emissions. Suites of community weighted functional traits associated with RBS, earthworm populations and their influence on terrestrial and aquatic GHG emissions, were also studied. The results suggest that the above mentioned parameters are all contributing to low GHG emissions from RBS. The study also assessed soil organic carbon (SOC) sequestration in RBS. The results indicate that the mean SOC content (0 to 30 cm depth) is higher in RBS in clay soils (142.20 t C ha⁻¹) than RBS in loam soils (115.08 t C ha⁻¹). The mean SOC in soils with deciduous trees is 157.19 t C ha⁻¹ and with coniferous trees is 117.48 t C ha⁻¹. Mean SOC content in RBS and adjacent AGL were 133.01 t C ha⁻¹ and 102.95 t C ha⁻¹, respectively, in the 0 to 30 cm soil depth

Preferred Platform: Poster Presentation

Student Presenter: No

CGU_B_02: Agricultural Management and Water Quality in Current and Future Climates

Conveners: Merrin Macrae¹, Jane Elliott², Henry Wilson³ and Nandita Basu⁴

Co-chairs: Merrin Macrae, Jane Elliott, Henry Wilson, Nandita Basu

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Landscape Legacies: Long-Term Nitrogen Trajectories in Human-Impacted Watersheds

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Global flows of reactive nitrogen (N) have increased significantly over the last century in response to land-use change, agricultural intensification and elevated levels of atmospheric N deposition. Despite widespread implementation of a range of conservation measures to mitigate the impacts of N-intensive agriculture, N concentrations in surface waters are in many cases remaining steady or continuing to increase. Such lack of response has been attributed to legacy N stores in subsurface reservoirs that contribute to time lags between conservation measures implemented on the landscape and water quality benefits realized in receiving water bodies. It remains unclear, however, what the magnitudes of such stores might be, and how they are partitioned between shallow soil and deeper groundwater reservoirs. In the present work, we have synthesized data to develop a comprehensive, 214-year trajectory of N inputs to the land surface of the Mississippi and Susquehanna River Basins. Based on this dataset, we have used the ELEMeNT model - which pairs a simulation of soil nutrient dynamics with a travel time-based approach - to reconstruct historic nutrient yields at the outlets of these watersheds and to model future N-loading under a range of scenarios. Our results show significant N loading above baseline levels in both watersheds before the widespread use of commercial N fertilizers, largely due to 19th-century conversion of natural forest and grassland areas to row-crop agriculture. Our modeling of future scenarios indicates 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. Our results suggest that significant time lags should be anticipated when aiming to reduce N export, and that both long-term commitment and large-scale changes in agricultural management practices will be necessary to meet such goals.

Preferred Platform: Oral Presentation

Student Presenter: N

Biogeochemical Asynchrony: Anthropogenic and Landscape Drivers of Nutrient Seasonality Across the Great Lakes Basin and Beyond

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Changes in climate, land use, and management are fundamentally altering both seasonal and event-scale patterns in ecosystem functionality. In recent decades, we have seen increases in the length of the growing season, warmer winters, and increasing numbers of freeze-thaw events during the winter season. In agricultural landscapes, which are already associated with higher loadings of nutrients to both streams and groundwater, tile drainage densities are increasing, changing water pathways and altering rainfall-runoff relationships. Dam building and reservoir development are also altering seasonal flow regimes and increasing the residence times of water and nutrients within the landscape, allowing for accelerated biogeochemical cycling across the river continuum. While seasonal nutrient dynamics are considered key to both stream metabolism and the development of eutrophication events in downstream water bodies, there has been little success in developing a comprehensive understanding of seasonal variations in nutrient export across watersheds or of the relationship between nutrient seasonality and watershed characteristics. In the present study, we have used concentration and discharge data from more than 200 stations across US and Canadian watersheds to identify (1) archetypal seasonal concentration regimes for a range of solutes, including nitrate, soluble reactive P, and total P, and (2) dominant watershed controls on these regimes across a strong gradient of climate, land use, and topography. Our results demonstrate that human activity is significantly altering nutrient concentration regimes, with large potential consequences for both in-stream metabolism and eutrophication risk in downstream water bodies.

Preferred Platform: Oral Presentation

Student Presenter: Y

The influence of snowmelt on phosphorus loss from Saskatchewan croplands and pastures

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Runoff can be a key contributor to the loss of phosphorus (P) from agricultural lands to water bodies, and beneficial management practices (BMPs) have been developed to minimize P loss. However, to maximize the benefit of BMPs it is important to understand the physical and chemical forms and concentrations of P in runoff, because physical and chemical P forms differ in their transfer mechanisms and their reactivity in the environment. The Canadian prairie region is unique in that its hydrology is characterized by long periods of winter, with half the annual precipitation occurring as snowfall. During spring snowmelt, there is a rapid release of water from snow packs when the mineral soil is frozen, resulting in high surface runoff, and accounting for the majority of nutrient loss in runoff in this region. Runoff volume is expected to vary among years, depending on the water content of the snowpack, which in turn could affect P losses in snowmelt runoff. From 2009-2016, research was conducted in SE Saskatchewan to study BMPs for the key agricultural practices in this region (annual crops and beef production). Within the study period, we had two wetter years with high runoff volumes and two drier years with little snowfall and thus reduced snowmelt runoff. We will present flow-weighted concentrations of total dissolved P, total particulate P and total molybdate reactive P for cropland and pasture sites throughout each annual snowmelt runoff event, and will compare changes during wetter and drier periods. We will also present results of analysis on dissolved and particulate samples from the start and end of the main runoff events in 2011 and 2013 by ^{31}P -NMR spectroscopy. These results will further our ability to manage P loss from agricultural soils in this region.

Preferred Platform: Oral Presentation

Student Presenter: N

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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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.

Preferred Platform: Oral Presentation

Student Presenter: Y

Biogeochemical hotspots: The importance of small water bodies in landscape nutrient processing

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Wetlands provide a wide variety of ecosystem services, including retention of sediment and nutrients, and subsequent improvements in downstream water quality. Although the processes controlling nutrient retention in wetlands are well known, there is a lack of quantitative understanding of the relative nutrient filtering abilities of wetlands of various sizes and in various landscape positions. Our inability to recognize the value of wetlands has led to their dramatic loss in the last few decades. Specifically, there has been an increased loss of small upland wetlands in agriculturally dominated regions. In this study, we use a meta-analysis approach to quantify the role of small wetlands in landscape scale nutrient processing. We synthesized data from 600 lentic systems around the world to gain insight into the relationship between hydrologic and biogeochemical controls on nutrient retention. Our results indicate that the first-order reaction rate constant (k) is inversely proportional to the residence time, across six orders of magnitude in residence time for total N, total P, nitrate, and phosphate. We then used a sediment-water model to show how nutrient removal processes are impacted by system size. Finally, the k -residence time relationships were upscaled to the landscape scale using a wetland size-frequency distribution. Results suggest that small wetlands play a disproportionately large role in landscape-scale nutrient processing—50% of nitrogen removal occurs in wetlands smaller than 500 m² in our example. Thus, given the same loss in wetland area, the nutrient retention potential lost is greater when smaller wetlands are preferentially lost from the landscape. Such findings are significant to wetland protection and restoration efforts, which have historically focused on maximizing total wetland area rather than on preserving a distribution of different wetlands sizes within a landscape.

Preferred Platform: Oral Presentation

Student Presenter: Y

An inverse modelling approach with equifinality control to investigate the dominant controls of snowmelt nutrient export in agricultural regions

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There is great interest in modelling the export of nitrogen (N) and phosphorus (P) from agricultural fields 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. In this study, a process-based N model, WINTRA, which is coupled to a physically based cold regions hydrological model, was expanded to simulate P and account for overwinter soil nutrient biochemical cycling. An inverse modelling approach using this model with consideration of parameter equifinality was applied to an intensively monitored agricultural basin in Manitoba, Canada, to help to identify the main climate, soil and anthropogenic controls on nutrient export. Consistent with observations, the model suggests that snow water equivalent, melt rate, snow cover depletion rate and contributing area for runoff generation determine the opportunity time and surface area for runoff-soil interaction. The simulations showed TDP concentration peaks generally arriving earlier than NO_3 , but also decreasing faster afterwards, which suggests a significant contribution of plant residue TDP to early snowmelt runoff. Fall tillage and fertiliser application increased both observed and simulated TDP concentrations in the subsequent spring snowmelt runoff but did not consistently affect NO_3 runoff. In this case, antecedent soil moisture content seemed to have had a dominant effect on winter soil N biogeochemistry, a process that is often ignored in models. This work demonstrates both the need for better representation of cold regions processes in hydrochemical models and the model improvements that are possible if these are included.

Preferred Platform: Oral Presentation

Student Presenter: N

Nutrient contributions from vegetation to runoff during snowmelt

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On the Canadian prairies the majority of nutrients transported from agricultural fields to surface waters are mobilized during snowmelt. Manures, fertilizers and soils are the commonly cited sources of these nutrients but contributions from vegetation can also be important. Perennial vegetation, fall-seeded crops and post-harvest residues contain varying levels of nutrients that can be released during the winter and transported during snowmelt runoff. During the past 10 years residues and vegetation from more than 50 fields in Saskatchewan and Manitoba have been sampled and the potential contribution of the plant material assessed using laboratory snowmelt simulations. Nutrient release is dependent on the species of the vegetative material and its 'greenness' in addition to the mass of material and its nutrient content. Interaction of nutrients released from the vegetation with surface soil was found to reduce the amount transported in runoff in some cases and the number of freeze-thaw cycles and presence of ponding also impacted potential losses. Comparison of the laboratory results with edge of field data aids in the identification of the processes involved in nutrient mobilization and transport from agricultural land during snowmelt.

Preferred Platform: Oral Presentation

Student Presenter: N

Runoff and nutrient export by overland flow and tile drainage in vertisolic clays of the Red River Valley in the Canadian Prairies

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Land management practices have the potential to reduce or amplify the water quality issues such as eutrophication and algae blooming in waterbodies and thus, the expansion of some of those practices, such as tile drainage in agricultural settings, is controversial. This study evaluated the quantity and quality of water from overland (OF) and tile (TF) flow from a tiled working farm in Southern Manitoba, Canada during the 2015 and 2016 seasons (Mar-October). Overland flow was the major contributing pathway to the total runoff, accounting for 75-85% of the edge of field losses throughout the season. Seasonal averages of flow weighted mean concentrations (FWMC) of soluble reactive phosphorus (SRP) and total phosphorus (TP) were substantially higher in OF (0.24 mg SRP L⁻¹, 0.35 mg TP L⁻¹) compared to TF (0.03 mg SRP L⁻¹, 0.05 mg TP L⁻¹), demonstrating that OF was the dominant P pathway. In contrast, seasonal averages of FWMC of nitrate (NO₃⁻) were substantially higher in TF (20 mg NO₃-N L⁻¹) than OF (8 mg NO₃-N L⁻¹). However, due to flow differences, NO₃⁻ loads were greater in OF (11 kg N ha⁻¹ yr⁻¹) than TF (4.8 kg N ha⁻¹ yr⁻¹). The majority of OF runoff (74 – 76 %) and OF nutrient losses were associated with the snowmelt and early spring period (March – May), whereas the most significant TF losses (49 – 82 % of seasonal TF) occurred during multi-day storms in late-spring (May to mid June). This work demonstrates that OF continues to be the dominant runoff and nutrient loss pathway from agricultural fields in the Red River Valley, despite the presence of tile drainage.

Preferred Platform: Oral Presentation

Student Presenter: Y

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

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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 Steppeler 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.

Preferred Platform: Oral Presentation

Student Presenter: N

CGU_B_02

Integrating Landowner Practices and Parcel Scale Information in Agricultural Watershed Models

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Watershed models are commonly used to prescribe land use policy on the basis of scenarios. These scenarios typically attempt to simulate the behavior of a watershed after changes to parcel scale changes to land management. However, it is actually uncommon that detailed, parcel scale information about the land management practices and environmental conditions is used in the development and parameterization of watershed models. This talk will describe a project currently underway to integrate a detailed land management survey into a series of agricultural headwater models.

Preferred Platform: Oral Presentation

Student Presenter: N

Too Much Phosphorous: Is Investment in Biogas Plants a Viable Alternative for Water Quality Improvement?

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Increased use of nutrients in intensive farming operations has led to higher crop yields and greater food security. At the same time, widespread use of commercial nitrogen (N) and phosphorus (P) fertilizers and large-scale livestock production have led to unintended environmental consequences, including eutrophication of both coastal and inland waters, threats to drinking water, and increased production of N₂O, a potent greenhouse gas. In the past, crop and livestock production were typically more integrated, allowing most livestock to be fed by local crops, and most livestock manure to be applied directly to nearby cropland. Under current intensive agriculture practices, however, there is frequently a spatial decoupling of crops and livestock, leading to hot spots of manure production and a lack of opportunities for cost-efficient and environmentally sensitive disposal. In recent years, there has also been increased interest in the use of both farm and regional-scale bioreactors to convert excess manure to energy, thus exploiting a renewable energy source and increasing the potential to recycle animal waste. In the present work, we develop a spatially distributed optimization approach to identify hotspots of manure production, and, using both economic and environmental criteria, evaluate the feasibility of (1) transporting manure for spreading on cropland to meet established nutrient requirements, and (2) constructing biogas reactors to process excess manure in areas where long-range transport is found to be infeasible. Although many assessments of the benefits of biogas reactors consider only benefits with regard to reductions in GHG emissions, we will explicitly incorporate benefits to water quality into our economic and environment criteria.

Preferred Platform: Oral Presentation

Student Presenter: Y

The influence of runoff event timing, antecedent moisture conditions, and soil fertility on phosphorus export from cropland in Manitoba

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Under normal climatic conditions a majority of annual water and phosphorus export from cropland in Manitoba occurs with snowmelt. However, higher frequency of rainfall driven runoff has been observed in the last decade in association with increases in high volume and intensity rain events. Water and phosphorus (P) export with surface runoff were measured between 2013 and 2017 from 18 small watersheds draining single agricultural fields and selected across a gradient of extractable soil phosphorus (3 to 25 mg kg⁻¹ sodium bicarbonate extractable P; Olsen-P) and tillage intensity (high frequency to long-term zero till). In most years, P export occurred primarily with snowmelt. Both flow weighted mean concentration (FWMC) and export of total and dissolved P with snowmelt correlated strongly with Olsen-P at 0-5cm, but higher concentration and export were also observed with higher antecedent soil moisture in the fall preceding snowmelt. FWMC of P observed with rainfall runoff events were observed to vary seasonally, with minimums observed for early spring events and maximums with early summer events where concentrations were as high as or higher than those observed with snowmelt. Potential drivers of this seasonality will be discussed in the context of fertilization practices and soil chemistry. The strong correlation identified between surface soil chemistry and FWMC will help to improve predictions of runoff P losses with snowmelt in Manitoba, but a pattern of increasing stratification of Olsen-P observed with less tillage indicates that modification of standard surface depth for testing (0-15cm) or interpretation of these tests are likely required for sites without tillage.

Preferred Platform: Oral Presentation

Student Presenter: No

The impact of straw incorporation in different soil depths on soil organic matter and crop yield in

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Black soil is one of important arable soil in China, tillage depth and straw incorporation both impacted the agricultural production of black soil. The impact of tillage depth and straw incorporation depths on maize and soybean yield were considered based on a three-year field experiment which is a split block design. The main treatments included shallow cultivation within 0-15 cm (D15), medium-shallow cultivation within 0-20 cm (D20), deep cultivation within 0-35 cm (D35) and 0-50 cm (D50), secondary treatments included contrast and straw incorporation (+S). Yields of maize and soybean were increased along with the increase in cultivation depth, and obtained the greatest values of 8999 kg/hm² and 2424 kg/hm², respectively, suggesting that the cultivation depth was an important factor impacting crop yield. Straw incorporation within 0-15 cm (D15+S), 0-20 cm (D20+S), 0-35 cm (D35+S), 0-50 cm (D50+S) were added after each cultivation depth treatment was split. Comparison with correspond no straw incorporation treatments, maize and soybean yields were decreased when cultivation depth was ≤ 20 cm, but were increased when cultivation depth was ≥ 35 cm, and obtained the greatest yield in D35+S treatments, which suggested that the depth of straw incorporation was key factor impacting the role of straw incorporation. Straw incorporated into soil increased SOM in a given soil layer, compared with D15+S treatment, SOM contents in D20+S, D35+S and D50+S treatments were decreased by 27.34%, 48.44% and 67.78%, however, the ratio of straw converted to SOM reached a greatest value in D35S treatment, and increased by 28.55%, 32.58% and 17.48%, compared with D15+S, D20S and D50+S treatments; Storage of SOM in different treatments showed in an increasing trend of D35+SD50+SD15+SD20+S. Therefore, combination of 0-35 cm cultivation depth and straw incorporation was recommended with the objectives of increasing crop yield and rainfall use efficiency in study site.

Preferred Platform: Oral Presentation

Student Presenter: N

Soil and water management for nutrient control in the Northern Great Plains

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The Northern Great Plains is a key region to global food production. It is also where eutrophication of surface waters due to nutrient enrichment is becoming a serious concern. Agriculture has been identified as a nutrient source and the industry is seeking to adopt beneficial management practices (BMPs) to protect surface water quality. Many BMP options are available but not all are suitable for implementation in the region. Here we review soil and water management 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. On the Northern Great Plains, 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.

Preferred Platform: Poster Presentation

Student Presenter: N

Hysteresis in tile flow rating curves: a case study from an Ontario farm

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Subsurface tile drains remove excess water from the upper part of the crop root zone within 24-48 hours after heavy precipitation from farm lands. Removal of the excess water from the root zone improves the success of the crops. In addition tile drains removing excess water from the field allow farms the plant crops earlier with the year. However, tile drains can also create water quality issues due to the preferential delivery of subsurface nutrients into surface water bodies. Many field studies require the hydrologic monitoring of tile drainage outlets. A common way for the measurement of flow rates in tiles is the development of rating curves and the estimation of drainage rates using continuously monitored water levels within the tile. However, in many cases, hysteresis in rating curves can complicate flow measurements. Hysteresis patterns in tile depth-drainage relationships can be indicative for the efficiency of the tile system, and can be related to a limited capacity of the pipe network, backwater effects, clogging or the age of the pipe. To separate the effect of backwater and clogging of the tile pipes, we recorded water levels and flow rates from a working farm field with a clay loam texture in southern Ontario. We found that the Manning equation predicted flow rates in tile accurately; however, the Manning roughness coefficient changed due to tile clogging and age of the pipe. We could find an almost similar trend for hysteresis in rating curve. Methods to improve estimates of tile drainage will be discussed. This work has implications for field studies and for an improved understanding of temporal variability in tile drain efficacy.

Preferred Platform: Poster Presentation

Student Presenter: N

Nitrate Leaching in a Warmer World

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Leached nitrate from agriculture poses environmental and human health concerns, such as groundwater contamination, and indicates an inefficient use of fertilizers. Nitrate leaching primarily occurs during the non-growing season. Climate change models predict warmer winters in temperate climates, and increased freeze-thaw cycle magnitude and frequency. Warmer winters could thus increase the concentration of nitrate in the soil, and intensify drainage events, leading to amplified nitrate leaching. Past research showed cover crops, and diverse crop rotations can reduce nitrate leaching, as well as stabilize crop yields. Cover crops reduce nitrate leaching by “catching” the excess nitrate, as well as increasing evapotranspiration to reduce drainage. There is a need for field studies that accurately simulate winter warming, to determine how it may interact with cover crop use to affect nitrate leaching reduction strategies. Soil solution samples from 90 cm and 140 cm depths were obtained weekly from 18 monolithic soil column lysimeters at the Elora Research Station. Nitrate concentrations were determined by colourimetric analysis. Drainage was measured using the weight data of the lysimeters and their drainage tanks. We used two soil types, clay loam and sandy loam, and two cropping systems, non-diverse and diverse, with a four species cover crop mixture. The latter provided greater diversity than previous studies of cover crop effects on nitrate leaching. Ceramic heaters, centered over six lysimeters, simulated winter warming. The heaters ensured the increased warmth was equivalent to 4°C greater than ambient air temperature. There were nine replicates of soil type and crop rotation, six replicates of winter warming, and a randomized complete block design was used to achieve three replicates of all experimental factors combined. Preliminary nitrate leaching results from spring 2017 will be shown, along with drainage patterns from the 2017-2018 non-growing season.

Preferred Platform: Poster Presentation

Student Presenter: Y

Are we unintentionally managing the nitrogen to phosphorus ratio of runoff?

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Both nitrogen (N) and phosphorus (P) fuel algal growth in eutrophic waterbodies, but large shifts in species composition, productivity, and trophic status have been observed where the relative supply of P is high relative to N (low N:P ratios). For many aquatic systems globally, losses of nutrients with runoff from upstream agricultural watershed is a significant driver of eutrophication. However, drivers of N and P export from agricultural land are frequently considered separately and there remains a lack of understanding of the impact of agricultural management on the ratio of N:P in runoff and the mechanisms controlling these patterns. To address this knowledge gap, we combine data from surface and subsurface runoff monitored at multiple experimental locations in Canada, U.S., and Sweden to evaluate the impacts of an array of agricultural management practices on the N:P ratio. These locations represent different climatic regimes ranging from temperate to cold climates. Agricultural management practices at sites included in the dataset include tillage, fertilization application, manure amendment, and crop management that the study regions had in common. We will present an overview of patterns observed across regions and the results of a preliminary analysis. For example, a common trend observed at sites both on the Canadian Prairie and in Sweden is a tendency for higher N:P ratios where land is cultivated rather than managed as no-till or converted to set-aside land. Potential links between management practices such as tillage and crop type will be discussed and analysed. Ongoing analyses will define whether patterns can be generalized across the study regions with differing climatic characteristics.

Preferred Platform: Poster Presentation

Student Presenter: N

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

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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.

Preferred Platform: Poster Presentation

Student Presenter: Y

Supply and transport limitations on phosphorus losses from agricultural fields in the lower Great Lakes region, Canada

Janina Plach, Merrin Macrae, Genevieve Ali, Richard Brunke, Michael English, Gabrielle Ferguson, Vito Lam, Tatianna Lozier, Kevin McKague, Ivan O'Halloran, Gilian Opolko, Christopher Van Esbroeck

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Phosphorus (P) runoff from agricultural fields is a significant environmental and economic concern in the lower Great Lakes region, impacting crop productivity and water-quality of downstream ecosystems. This field-based study evaluates the relative role of hydrologic versus biogeochemical controls on P export (surface runoff and tile drainage) from 9 agricultural fields across Southern Ontario, Canada. Edge-of-field water samples were collected over 5 years (2011- 2015 inclusive) from fields varying in soil textures (clay to sandy-loam) and similar P conservation and best management practices (BMPs). The goal was to characterize the loading response of P (soluble reactive P (SRP) and total P (TP) loads) as transport-limited (i.e., chemostatic) or supply-limited, and to evaluate whether stormflow P export (event-based) can be predicted from soil test P concentrations. Establishing the chemostatic versus episodic behaviour of P export is fundamental to designing BMPs for reducing P losses during key runoff periods in the growing and non-growing seasons across the region. These results, characterizing P loadings linked to discharge and soil P availability, and their implications for predicting the risk of P movement from agricultural landscapes to surface waters will be presented.

Preferred Platform: Poster Presentation

Student Presenter: N

Phosphorus losses from agricultural fields in Ontario, Canada: Implications for land management efficacy in cold regions

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Agricultural phosphorus (P) losses are a growing global economic and water-quality concern in cold weather regions. An improved understanding of the magnitude, form and transport flow paths of P losses from agricultural fields, and, the climatic drivers of these processes is needed to apply and evaluate appropriate beneficial soil management practices (BMPs) to protect soil-water quality now and under future changing climates. This study examines year-round, high-frequency edge-of-field P losses (dissolved reactive P (SRP) and total P (TP)) in surface runoff and tile drainage from croplands in Ontario, Canada under corn-soybean-winter wheat rotation, where multiple BMPs are used (e.g. nutrient management, rotational conservation tillage, periodic use of cover crops). Annual (2011-2016) and seasonal runoff and P loading from croplands of varying soil-textures (loam to clay-textured) will be presented (2 full crop rotations), and the relative contributions of tile drainage and surface runoff to P budgets and speciation will be discussed. These results, estimated annual field budgets for P (i.e., fertilizer inputs, crop uptake, runoff and soil storage) and the potential efficacy of individual and combined BMPs (e.g., timing of fertilizer application) for mitigating P movement from agricultural landscapes to surface waters in cold weather climates will be discussed.

Preferred Platform: Poster Presentation

Student Presenter: N

Mobilization of Phosphorus in frozen and unfrozen soil under no-till agricultural management with different fertilizer application strategies

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Phosphorus (P) from agricultural fields contribute to P loading to surface water and the occurrence of algal blooms. Tile drains are an important pathway for P loss from fields under no-till management, particularly when P is surface applied. However, recent studies in Ontario found that P losses from tile drains were not enhanced under no-till systems where P was applied via subsurface placement. Further, freeze-thaw cycles may affect P transport in soils during winter, a critical time for P loss. This study explored interactions between infiltrating water and the supply of P over a simulated non-growing season using a laboratory-controlled experiment to understand how fertilizer placement (surface broadcast or subsurface placement) influenced P leaching through soil profiles. The objectives were to: 1) investigate the movement of water through soils under different antecedent temperature conditions (frozen vs unfrozen); 2) quantify the mobilization of P through the soil profile under different P application strategies, and 3) relate the movement of P to subsurface flowpaths and determine if this differs between soil textures (clay vs silt loam). Intact soil monoliths (~30 x 30 x 30 cm) of were fertilized via subsurface placement or surface broadcast. Soil monoliths were then treated with simulated rainfall under thawed (+10 °C) and frozen (-10 °C) conditions. Conservative tracers (Br⁻, Cl⁻, D₂O) were sequentially applied to characterize subsurface flow paths. Matrix flow dominated unfrozen silt loam soils, while preferential flowpaths were observed in unfrozen clay and in both soil types under frozen conditions. Subsurface placement of fertilizer reduced subsurface P losses in no-till soils, and was particularly effective in clay soils prone to preferential flow. Results demonstrate the competitive advantage of subsurface placement of fertilizer in the reduction of subsurface P leaching by limiting the interaction of the P supply with preferential flow pathways.

Preferred Platform: Oral Presentation

Student Presenter: Y

Dominant glacial landforms in the Lake Erie watershed exhibit differences in soil chemistry and potential risk of phosphorus loss

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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 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) from 8 agricultural fields in the lower Great Lakes region of Ontario, Canada, and Indiana and Ohio, USA. Surficial, subsurface (plough layer) and deep soils (to till depth) were collected in 2016 and were analyzed for particle size, composition, total Pi concentrations (legacy Pi), Pi sorption capacity, Pi saturation conditions and solid-phase Pi partitioning. Results show regionally diverse soil Pi retention as well as potential subsurface water transport pathways. These inherent differences in soil physical and chemical properties in the landscape, and the implications for Pi mobilization from agricultural soils in the contrasting glacial landforms found within the Lake Erie watershed will be discussed.

Preferred Platform: Oral Presentation

Student Presenter: N

Phosphorus loss through tile drains: Putting it in perspective

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There has been much effort in recent years to quantify phosphorus (P) losses through tile drains, which has generated a great deal of data that is bringing us closer to understanding the role of tile drains in the transport of P from agricultural land. What is missing from the interpretation of this data, however, is the context that will allow us to integrate results from different areas that do not seem to align, and to predict the net impact of tile drains on P transport in areas of different soil types and topography. This presentation will provide an overview of our current understanding of the role of tile drains both in water partitioning and P transport, discuss the challenges of incorporating this understanding into models, and the implications of the relevant processes to P losses at a field and watershed scale.

Preferred Platform: Oral Presentation

Student Presenter: n

The impact of straw incorporation in different soil depths on soil organic matter and crop yield in

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Black soil is one of important arable soil in China, tillage depth and straw incorporation both impacted the agricultural production of black soil. The impact of tillage depth and straw incorporation depths on maize and soybean yield were considered based on a three-year field experiment which is a split block design. The main treatments included shallow cultivation within 0-15 cm (D15), medium-shallow cultivation within 0-20 cm (D20), deep cultivation within 0-35 cm (D35) and 0-50 cm (D50), secondary treatments included contrast and straw incorporation (+S). Yields of maize and soybean were increased along with the increase in cultivation depth, and obtained the greatest values of 8999 kg/hm² and 2424 kg/hm², respectively, suggesting that the cultivation depth was an important factor impacting crop yield. Straw incorporation within 0-15 cm (D15+S), 0-20 cm (D20+S), 0-35 cm (D35+S), 0-50 cm (D50+S) were added after each cultivation depth treatment was split. Comparison with correspond no straw incorporation treatments, maize and soybean yields were decreased when cultivation depth was ≤ 20 cm, but were increased when cultivation depth was ≥ 35 cm, and obtained the greatest yield in D35+S treatments, which suggested that the depth of straw incorporation was key factor impacting the role of straw incorporation. Straw incorporated into soil increased SOM in a given soil layer, compared with D15+S treatment, SOM contents in D20+S, D35+S and D50+S treatments were decreased by 27.34%, 48.44% and 67.78%, however, the ratio of straw converted to SOM reached a greatest value in D35S treatment, and increased by 28.55%, 32.58% and 17.48%, compared with D15+S, D20S and D50+S treatments; Storage of SOM in different treatments showed in an increasing trend of D35+SD50+SD15+SD20+S. Therefore, combination of 0-35 cm cultivation depth and straw incorporation was recommended with the objectives of increasing crop yield and rainfall use efficiency in study site.

Preferred Platform: Oral Presentation

Student Presenter: N

CGU_G_01: Gravity, Geoid and Height Systems

Conveners: Marc Véronneau¹, Daniel Roman²

Co-chairs: Jianliang Huang¹, Yan-Ming Wang²

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Common Datasets for Geoid Modeling in North America

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The Canadian Geodetic Survey (CGS), Mexico's Instituto Nacional de Estadística y Geografía (INEGI), and NOAA's National Geodetic Survey (NGS) have recently undertaken a collaborative project to incorporate all the individual datasets used in our geoid modeling processes into a common dataset. The ultimate goal of this project is to produce a more consistent geoid model, which ultimately provides more consistent GNSS-derived orthometric heights for all of North America. Currently, geoid models produced by each of our agencies has differences caused by two sources: computational differences and input dataset differences. By agreeing on the latter, differences between various geoid models are caused only by computational differences. Datasets included in this project include surface gravity data, shiptrack data, airborne data (GRAV-D and from other sources), a Digital Elevation Model (DEM), altimetric gravity data, a satellite gravity model, and a geopotential model. We will present a number of these common datasets that have been completed as of early 2018 including the surface gravity data and a Digital Elevation Model, as well as stand-alone products and models that are used in our projects and available via other groups including altimetric gravity data, a satellite gravity model, and a geopotential model.

Preferred Platform: Oral Presentation

Student Presenter: N

Analysis of GRACE Terrestrial Water Storage Anomaly versus Snow Water Equivalent

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In this study, the spatial and temporal variabilities of terrestrial water storage anomaly (TWSA) information obtained from the Gravity Recovery And Climate Experiment (GRACE) twin satellites data were analyzed in conjunction with multisource snow water equivalent anomaly (SWEA) over several basins in the Canadian landmass. Snow water equivalent (SWE) data were extracted from three different sources: the European Space Agency (ESA) Global Snow Monitoring for Climate Research (version 2.0 – GlobSnow2), the Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E), and the Canadian Meteorological Center (CMC). The objective of the study was to understand whether SWE variations have a significant contribution to terrestrial water storage anomalies in the Canadian landmass. The period considered was from December 2002 to March 2011. Significant relationships were observed between TWSA and SWEA for most of the 19 basins considered (63% to 84% of the basins, depending on the SWE products considered). The best results were obtained with the CMC SWE products, compared to satellite-based SWE data. In the Mackenzie Basin, GRACE-derived TWSA was well correlated to SWEA ($R = 0.7$). In sub-basins such as Liard or Fraser in Western Canada, which are snow dominated-basins, SWEA explains most of the variabilities of TWSA ($R = 0.8$). However, despite the high snow accumulation in the Northern Québec Labrador Basin, GRACE showed weak or insignificant correlations with SWEA, regardless of the data sources. The same behavior was observed in the Western Hudson Bay Basin. This may be explained by several issues, especially the subseasonal changes of GRACE terrestrial water storage, related to fluctuations in atmospheric forcing (precipitations). The residual effects of glacial isostatic adjustment may also influence the quality of GRACE data around the Hudson Bay. Overall, the results found indicated the important role of SWE on terrestrial water storage variations.

Preferred Platform: Oral Presentation

Student Presenter: Y

NUMERICAL SIMULATION OF ASTEROID SURFACE GRAVIMETRY

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Asteroid density is a fundamental physical parameter for the understanding of asteroid composition and formation, and thus an integral part towards understanding of the formation of the solar system. Yet, our information about asteroid density and mass distribution is very limited. Photometric, spectrometric and albedo were used to estimate asteroid mass. Also, radio tracking from orbiting satellites was employed in the past. However, those estimates are affected by large uncertainties, especially for small asteroids. As an alternative observation technique, asteroid surface gravimetry can provide improved information on mass and density distribution. In this study, we use forward modelling of different asteroid density models (e.g., Bennu, 25143 Itokawa, 2008 EV5) to estimate surface gravity. Results will also be used to determine the survey requirements for the Gravimetric Asteroid Surface Probe (GRASP) mission, a proposed Canadian asteroid lander mission. Different density models are used to analyse if homogeneous and heterogeneous density distributions could be distinguished from surface gravimetry (including centrifugal acceleration). The gravity differences between homogenous and heterogeneous density distributions (on the order of milliGal (microG)) are in fact resolvable from surface measurements considering a state-of-the-art space gravimeter (e.g. VEGA by Gedex Inc.). Hence, inversion models of such data could be used to determine the structure of asteroids and thus shed light on their evolution.

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Student Presenter: Y

Performance of recent Earth Gravitational Models over North America

Jianliang Huang, Marc Véronneau, John Crowley, Yanming Wang, Xiaopeng Li, Kevin Ahlgren,
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An Earth Gravitational Model (EGM) will be selected for the realization of a geoid model towards the North American – Pacific Geopotential Datum of 2022 (NAPGD2022). This EGM, which is used to determine the long- and medium-wavelength components of the geoid model in a remove-compute-restore Stokes method, can be either satellite-only or satellite-terrestrial-combined. A satellite-only EGM is theoretically preferable because it is independent from the terrestrial gravity data while a combined EGM is practically more useful because it has a higher maximum spherical harmonic degree, which reduces the Stokes truncation error and geoid residual. In this study, recent EGMs are spectrally combined with a common set of terrestrial gravity data using different Stokes kernel modification (120, 150, 180, 210, 360, 720, 1440, 2160). The resulting models are evaluated against GPS-levelling data, surface gravity measurements, deflections of the vertical and satellite altimetry data over the Great Lakes. The analysis includes five GRACE/GOCE models and seven combined models (EGM2008 (US NGA), CnmrefA (US NGS), CnmrefB (US NGS), Geco (Italy), GOCO5c (TUM Germany), XGM2016 (TUM Germany), and EIGEN6C4 (GFZ Germany)). A preliminary EGM will be recommended for the realization of NAPGD2022 based on this evaluation.

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Student Presenter: N

CGU_G_01

GRACE in Differential Mode

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The potential of using GRACE mission non-gravitational accelerations to derive common and differential mode accelerations is assessed. This study takes advantage of GRACE A and B spacecraft spatiotemporal difference to generate common and differential mode accelerations (CM and DM respectively) via a series of spatiotemporal transformations. GRACE Level1b measurements spanning an entire year are used to create CM and DM maps. Results are evaluated using GOCE mission gradiometer measurements of the same period. A good agreement between GRACE-DM and GOCE-DM is revealed. GRACE CM maps show strong magnetic signatures over the North and South poles in the range of $\pm 5 \text{ nm/s}^2$ along the orbit, and strong presence of the magnetic declination signal over the equatorial region in DM maps. Orbits are separated in ascending and descending tracks and are further classified in day and night tracks. Intriguingly, ascending day and night tracks are highly correlated with the Earth's magnetic field. Pe

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Student Presenter: Y

Update to IGLD 2020 Geodetic Analysis at Great Lakes NWLON Stations

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As a part of the update to the International great Lakes Datum for 2020 (IGLD 2020), dynamic heights will be defined through positions defined by Global Navigation Satellite Systems (GNSS) and a geopotential model. The North American Pacific Geopotential Datum of 2022 will be realized in 2022. This suffices for IGLD 2020, because that datum will be finalized in 2025. The current IGLD 85 datum was based on geopotential values determined as a part of the North American Vertical Datum of 1988 (NAVD 88) finalized in 1991. These geopotential numbers were determined from an adjustment of leveling measurements across North America and reduced to geopotential numbers using interpolated gravity from a fixed gravity database. Significant errors exist in NAVD 88, and thus in IGLD 1985, as a result of the adjustment. For IGLD 85 mismatches at the dm-level were accounted for using hydraulic correctors (HC). These HC were thought to have derived from uncertainties in the level surface as well as standing water topography issues. The intent of this update is to move to eliminate the uncertainties associated with the geopotential model and focus on the water topography. NAPDG 2022 will define the geopotential values more consistently and accurately than was accomplished as a part of the NAVD 88's adjustment. There are several models available as predecessor models leading to NAPGD 2022. The most recent is xGEOID17B, which is examined here. Geometric coordinates determined as a part of the IGLD 2015 GPS campaign are used in conjunction with the xGEOID17A/B models to derive estimates of dynamic heights. These are compared around the respective Lakes to estimate water topography. The expectation is a reduction cm-level for remaining HC to account for water topography issues.

Preferred Platform: Oral Presentation

Student Presenter: N

The challenge in updating a geoid-based vertical datum

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For the Canadian Geodetic Vertical Datum of 1928 (CGVD28), its access was through benchmarks having published heights by governmental agencies. A benchmark often had the same height for a long time because it was not re-observed for a few decades or ever. Even when the Canadian Geodetic Survey (CGS) re-observed these benchmarks, heights were barely changing, unless a benchmark was locally unstable, because each end of the levelling lines was constrained to official heights. This process did not allow the recovery of the regional uplift or subsidence or national distortion in the datum. However, it rendered a consistent vertical datum for users. In 2013, CGS replaced CGVD28 with CGVD2013, which is accessible by a geoid model, and does not require the use of benchmarks. As any models, a geoid model is never perfect as it is limited by the theory behind it, the quality and distribution of the data to build it and its computational procedure. Furthermore, new models can be cranked up daily each having differences between them depending on the process used. Naturally, the publication of several models is not practical, but new models need to be published occasionally to improve the datum realization. The updated models may include regional corrections where new data are available or national improvement if based on a new global gravity model. As the publication of new models is inevitable, CGS is looking into a process to inform clients. This can include a document describing rational in the differences, naming convention, and figures showing regions where changes are larger than, e.g., 2, 4 and 8 cm, and regions where changes are larger than 1, 2 and 3 sigma with respect to the error estimates. Naturally, the unification of the vertical datums for North America by 2022 will bring new challenges, as it will require agreements between the different countries.

Preferred Platform: Oral Presentation

Student Presenter: N

Effect of gravity and topographic reductions on geoid computations

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The gravity and topographic reductions are used to reduce the surface gravity to the level surface or to sea level depending on various geoid computation theories. Because the theories deal with the reductions differently, the resultant geoid models are different. If we assume the geoid computation theories are equivalent, differences in the model will only be caused by differences in the reductions and associated corrections to the geoid. In this paper, we compute the geoid in Iowa where the terrain is relatively smooth but the effects of the Rocky Mountains are still felt, and in Colorado where the topography is high and rough. The following methods are used: A) the xGEOID17 type of solution; B) Solution using Bouguer anomaly for gravity data interpolation; C) Solution using Faye anomaly. The geoid models are compared with the GPS/leveling data of GSVS14 in Iowa, and the historical GPS/leveling data in Colorado. The spherical harmonic coefficient model PGM201, which uses GOGO05S satellite gravity model for its low degree and order components, and it is used as the reference model to compute the geoid in the remove-restore fashion with Wong-Gore kernel truncation. The optimal truncation degrees is determined by the GPS/leveling data comparisons. The goal of the paper is to exam the differences in the geoid models, and to find the optimal methods and parameters for the geoid computation using gravity and topographic data.

Preferred Platform: Oral Presentation

Student Presenter: N

Requirements in absolute gravimetry for the gravity network in Mexico.

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In this report we introduce the action plan to establishing a set of 12 absolute gravity observation sites, with a specific aim to support the improvement of the gravimetric reference frame in Mexico. The progress in this plan includes the design of a functional site distribution, accuracy requirements, selection of devices, selection of specific sites and a formal participation link between the Mexico National Institute of Geography and Statistics (INEGI) and the US National Oceanic and Atmospheric Administration (NOAA). Currently the geodetic gravity network is formed by more than 400 base stations, established with the use of relative gravimeters. The gravity value associated to each base is meant to provide the access point to a consistent reference frame for local surveys throughout the country. Among its applications, the network is expected to work as a fundamental source to modeling the gravity field and geoidal heights; which ultimately enables the precise vertical positioning by GNSS. The current strategy to re-define the gravity values at base stations is an answer to fulfill the accuracy standard of 0.02 miliGal. There are several challenges to be overtaken in order to achieve such level of uncertainty in the field. A wide variety of local conditions and instrument limitations have to be accounted in order to lower the total error budget to 0.01 miliGal in each: absolute and relative observations.

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Student Presenter: N

CGU_G_01

Gravity calculation using global crustal and mantle seismic models

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We present a new plugin in the state-of-the-art finite element code ASPECT which is used to predict gravity anomalies in spherical geometry. We incorporate both the CRUST 1.0 crustal model (Laske et al., 2013) and S40RTS shear-wave velocity tomographic model in the Earth's mantle (Ritsema et al., 2011) which enable us to obtain a global density field. We additionally solve the Stokes equations over a few timesteps and let the system relax to isostatic equilibrium. Due to the difference in data format of both crustal and mantle models, we explore various scalings for converting velocities to densities along with how to bridge the overlap region of the models. We test the sensitivity of the gravity prediction to model resolution and additional local mesh refinement. We also compare model outcomes using either a free slip or free surface.

Preferred Platform: Poster Presentation

Student Presenter: N

An Update on the Vertical Deflection Models over North America Based on GRAV-D

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Significant amount of GRAV-D airborne gravity data have been collected over CONUS and Alaska with about 200km penetration into Canada and Mexico territories around the borders, which improves both the accuracy and the resolution of the gravity field model in this region. A series of experimental geoid models based on the GRAV-D data have been published by NGS and show 20 cm geoid improvements (verified with independent data sets) and upwards of 50 cm geoid changes (unverified due to lack of independent observations). This study will incorporate these GRAV-D contributions together with other improvements on the digital elevation model, the surface gravity cleaning, and corrections on the curvature of the plumb line into an updated vertical deflection model. Both the individual changes due to different updates and the overall changes on the vertical deflection models will be analyzed and evaluated with existing surface observations (both historical DoVs and newly acquired DoV's along the GSVS lines).

Preferred Platform: Poster Presentation

Student Presenter: N

Survey Design and Aircraft Testing for an Airborne Gravity Survey of the U.S. Pacific Islands

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The U.S. National Geodetic Survey's Gravity for the Redefinition of the American Vertical Datum (GRAV-D) project is collecting airborne gravity data to support a 1 cm geoid. This project will collect airborne gravity data over the entire U.S. and territories by 2022. One particularly difficult area to survey is the U.S. Pacific Islands, including Hawaii, Guam and the Commonwealth of the Northern Mariana Islands (CNMI), and American Samoa. These areas have sparse terrestrial gravity data and ship tracks that have poor metadata. The airborne gravity data will be extremely important to provide consistent coverage for the area and connect the land, shallow water, and ocean regions. However, there are many challenges to operating in remote areas and collecting high quality data. The GRAV-D project will conduct a three to four month airborne gravity survey of the U.S. Pacific Islands starting in December of 2018. Besides a recent relative gravity survey in Guam and CNMI, most of the surface gravity data on the islands are from historical surveys with very little metadata. The paper will summarize the airborne survey plan, including include details of the instrumentation, flight plans, and operations to cover the region efficiently, and provide test results of the NOAA Gulfstream IV aircraft that we will use. We conducted the test survey out of the NOAA Aircraft Operations Center in Lakeland, Florida in February 2018, collecting data over the U.S. southeast coastal area. Although not a remote location, this survey proved that the aircraft and instrumentation configuration was successful and provided lessons learned in advance of the challenging survey in the Pacific Islands.

Preferred Platform: Poster Presentation

Student Presenter: N

An Updated Realization of NAD83(CSRS) for Canada

Michael Craymer, Remi Ferland, Earl Lapelle, Mieczyslaw Piraszewski, Catherine Robin,
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The North American Datum of 1983 (NAD83) is the geometric reference frame of the Canadian Spatial Reference System (CSRS) that has been adopted by government agencies for georeferencing in Canada. In collaboration with the U.S., NAD83 was redefined in 1998 as a seven-parameter Helmert transformation from ITRF96. Referred to as NAD83(CSRS), the frame was kept aligned with the North American tectonic plate using the NNR-NUVEL-1A plate motion model. NAD83(CSRS) has since been updated to later realizations of ITRF using the transformations between ITRFs published by the IERS and identified by version numbers. In order to account for crustal motions within the NAD83(CSRS) frame, a crustal velocity model based solely on GPS velocities was introduced with version 5 (based on ITRF2005) and updated in version 6 (based on ITRF2008). The velocity model, represented by an interpolation grid, enables coordinates to be propagated to different reference epochs, including those of the realizations of NAD83(CSRS). These velocity models were unreliable in the northern territories where GPS coverage was sparse. A new NAD83(CSRS) version 7 has recently been published based on a transformation from ITRF2014 and a reprocessing of all continuous and high accuracy repeated GPS campaign surveys in Canada, bordering areas of the U.S. and all of Greenland. A set of approximately 80 global IGS stations used for alignment to IGS14. To overcome the weakness of the previous GPS-only velocity models, a new model was created based on a novel integration of GIA models with the new GPS velocity field. In addition to providing a more precise regional reference frame for geospatial positioning throughout all of Canada, the new NAD83(CSRS) version 7 is capable of providing more accurate predictions of crustal velocities for propagating coordinates to different reference epochs and for supporting geoscience studies such as natural hazards related to earthquakes and relative sea level rise.

Preferred Platform: Oral Presentation

Student Presenter: No

CGU_G_01

**Criteria for Selection Continuous GNSS Sites through North America in Support of
NATRF 2022**

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In 2022, the U.S. will adopt a new reference frame for North America tied more explicitly to the International terrestrial Reference Frame. To account for a bulk of the plate motion, an Euler pole of rotation will be determined from select sites. Hence, the selection of such sites is critical to the definition of the new North American Terrestrial reference Frame in 2022 (NATRF 2022). Several considerations must be taken into account. For starters, the motion at all sites in North America cannot be simply expressed by a horizontal plate rotation. Significant uplift, subsidence and intra-plate motions exist that would muddy such a solution. Site selections for determining Euler Pole Parameters (EPP) must take this into account. Once a best fit EPP is determined, all available sites would be utilized to better assess these intra-frame velocities. Site selections are available from numerous Continuously Operating Reference Stations (CORS) as well as Canadian Active Control Stations (CACS). A significant uplift signal is the Glacial Isostatic Adjustment in the central Canadian through the Great Lakes region. Several CACS are conveniently located on the suspected uplift domes, which would minimize distortions in the EPP estimates deriving from GIA signal. Several CORS are located sufficiently far from the GIA signal to likewise serve as reliable inputs. This paper will discuss some proposals towards these selections and start dialog that will be pursued in follow on working groups focused on development of the EPP.

Preferred Platform: Oral Presentation

Student Presenter: N

CGU_G_01

Preliminary results of the IGS and CORS data reprocessing at the National Geodetic Survey

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On January 29 2017 (GPS week 1934), the International GNSS Service (IGS) has adopted the IGS14 reference frame after the combination of over 20 years of time-series reprocessed by various IGS analysis centers. The National Geodetic Survey (NGS) has reprocessed the IGS global tracking data since 1994 independently, and the GPS orbits and Earth Orientation Parameters (EOPs) were compared with the recent IGS combined solutions. The observation data from NGS' Continuously Operating Reference Stations were also reprocessed based on the same reference frame. As a result, the position and velocity of each station is soon to be updated. Compared to the first reprocessing campaign, over 900 new stations established after the first reprocessing campaign will have the computed velocities.

Preferred Platform: Poster Presentation

Student Presenter: N

CGU_H_01: General Hydrology

Conveners: Claire Oswald¹, and Daniel Peters²

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Session Description

This session invites contributions from all aspects of hydrology, in particular those not covered by a special session.

Primary Affiliation: CGU / Hydrology

Mapping of Wet Snow in Apex River Watershed, Nunavut, Canada from RADARSAT-2

Yulia Antropova, Alexander S. Komarov, Murray Richardson, Koreen Millard, Keegan Smith

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Mapping of wet snow during the spring melt period is important in order to understand and predict snowmelt runoff and the resulting freshwater resource supply. In this study, we 1) relate time-series evolution of C-band radar backscatter and scattering contributions to ground-based snow cover observations in view of wet snow detection, and 2) evaluate the ability to detect and map wet snow using time-series RADARSAT-2 images. Nine Fine Quad and four Spot Light RADARSAT-2 images were acquired over the Apex River watershed, Nunavut, Canada from April 24 to June 28, 2017. In support of SAR observations, optical Planet satellite images with 3m resolution were collected to derive ground-truth snow-covered and snow-free areas. Furthermore, in-situ meteorological station data and ground-based camera time-series images were collected. Our results suggest that cross-polarization (HV) backscatter from snow significantly dropped by approximately 12 dB when the air temperatures become positive and moisture in snow started to appear. HH and VV backscatter from snow also decreased by approximately 7 dB. Backscatter difference between snow and bare ground is large in the beginning of snow melt and decreases towards the end of the melt period. Freeman–Durden decomposition analysis showed that volume scattering contribution drops drastically when moisture in snow starts to appear, and surface scattering dominates when snow becomes wet. Timing of the melt onset can be readily inferred from the changes of backscatter signal. Classification of HV SAR images based on a threshold approach shows high overall accuracy of 85.9% when compared against Planet images.

Preferred Platform: Oral Presentation

Student Presenter: Y

The influence of winter processes on the hydrology of a constructed wetland in the Athabasca Oil Sands Region, Alberta: six years after construction.

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Constructed wetlands are a critical component of the post-mining landscape in the Athabasca Oil Sands Region (AOSR). Their sustainability depends on system hydrology much of which comprises of winter processes as snow covers the landscape for 5 to 6 months and is ~25% of the annual precipitation. To date, there are few studies that explore the snow hydrology of reclaimed ecosystems in the AOSR, with snowmelt runoff from hillslopes identified as a dominant mechanism of delivering water to wetlands. To address this shortcoming, six years (2013-2018) of snowmelt energy balance data, distributed snow surveys and one year of intensive melt observations from the Sandhill Fen Watershed (SFW) is used to 1) establish the driving factors that determine the distributed disposition and melt of the snowpack, and 2) evaluate whether upland hillslopes contribute significant snowmelt runoff to adjacent lowlands. Four meteorological towers including one station with an eddy covariance system were used to quantify energy transfer into the snowpack. Snow surveys and continuous SWE measurement at different locations allowed accounting of energy transfers, whereas soil moisture arrays and in 2018 runoff collectors allowed an assessment of recharge versus lateral water transfers. Snow accumulation typically occurred mid-October with melt complete in early April. Over the six years, SWE ranged from 40 mm to 110 mm on average, with considerable variability based on topographic position. Melt was rapid driven largely by radiative fluxes. Unlike results previously reported, surface runoff from uplands was small, which may be a result of low snowfall in 4 of the 6 years. In 2018 average SWE was ~80 mm, runoff from hill-slopes was observed, yet runoff ratios remained 20%. Snow accumulation and melt are dynamic and an important source of water for reclamation ecosystems, yet design and construction practice have a large role on the vertical versus lateral partitioning of meltwater.

Preferred Platform: Oral Presentation

Student Presenter: Y

Physically based stream temperature modeling of a steep proglacial stream

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There is ongoing concern about the effects of glacier retreat on stream temperature and the implications for aquatic ecology. The application of physically based models to assess the effect of glacier retreat is complicated by the heterogeneity of proglacial stream morphology, the diurnal fluctuations of stream flow, and the effects of aeration on stream albedo. There are also questions about whether the “wind functions” typically used to model the sensible and latent heat fluxes over streams are applicable for highly aerated flow, which should enhance those exchanges. The goal of this study was to develop approaches to parameterize these influences for inclusion in stream temperature models. The study focused on a 1-km-long reach of South Creek, a steep glacier-fed stream in the Bridge Glacier valley in British Columbia. Field work was conducted in July-September 2017. The reach was divided into four sections based on variations in slope and morphology. Weather stations at the upper and lower end of the reach measured air temperature, humidity, wind speed, net radiation, and reflected solar radiation over the stream. A third station recorded incident solar radiation, precipitation, air temperature and humidity, and wind speed. Photogrammetric analysis of imagery taken from a drone was used to document variations in stream width and aeration at a range of stream discharges. Salt dilution gauging and water level recorded using pressure transducers were used to compute streamflow at the upper and lower ends of each stream section, as well as to compute relations between velocity and discharge. Stream temperature was recorded continuously at evenly spaced intervals along the reach. An energy-budget model will be applied to each study section to assess the relative roles of the surface energy exchanges, with a particular focus on the effects of aeration.

Preferred Platform: Oral Presentation

Student Presenter: Y

Determining the Impact of intersite correlation on flood quantile estimates in a pan-Canadian analysis using copulas and super regions.

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Several applications in water management require accurate estimation of flood quantiles where no hydrometric data are available. The Region of influence (ROI) is a well-established method to create groups of relevant gauged sites inside which a regression model can be used to estimate flood quantiles at ungauged locations. For practical reason, such analysis is generally carried out at a provincial level. However, Canada possesses a vast diversity of climatic and flood regimes that do not coincide with administrative boundaries. Alternatively, this study defines super regions based on the classification of sites according to their drainage area and mean annual precipitation. Results show that super regions provide a meaningful and effective partition for carrying out a nationwide analysis. Regression using Generalized Least-Squares (GLS) is largely recognized as good practice to account for unequal sampling error and intersite correlation. However, GLS has not been widely considered in Canada. One reason may be the additional step for estimating the covariance structure between sites, in particular when periods of annual record does not perfectly overlap. The present study compares different covariance models and examines their impact on the accuracy of the flood quantile estimates. It is shown that a smooth spatial model provides a satisfactory representation of the sampling error. In addition, the extremal nature of intersite correlation is investigated using copulas.

Preferred Platform: Oral Presentation

Student Presenter: No

Monitoring turbidity from above: Can drones be used to image in-stream turbidity?

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Turbidity represents an important measure of water quality related to the transport of contaminants, health of aquatic life, and downstream sedimentation. Typically, footprints for turbidity are limited to an optical sensor deployed in the water column to capture measurements through time, or time-intensive measurements made by hand to gather spatially distributed observations. To join these two types of data collection, we tested the ability of multispectral imagery collected via drone (also known as unmanned aerial vehicles) to be used as a proxy for observations of river turbidity. Images were collected along Onondaga Creek, a third order stream in Syracuse, NY, with known elevated turbidity from the upstream geologic condition. We tested two different drone platforms, a fixed wing and a quadcopter, across several days of flights representing different environmental conditions. Images were captured of both natural in-stream turbidity as well as turbidity induced by several field workers kicking up sediment to create a plume. Flights were paired with in situ data collection to compare a multispectral 'turbidity index' relating near-infrared and visible light bands to in-stream turbidity measurements. We found a strong relationship between turbidity index values and turbidity across the full range of measurements, particularly when including the induced turbidity measurements. However, we also found that environmental conditions could confound multispectral data collection. We offer cautious optimism for the use of drones to observe turbidity from the sky, with several 'lessons learned' regarding future use of these tools.

Preferred Platform: Oral Presentation

Student Presenter: No

Experimenting the petroleum hydrocarbons spill onto peat to characterize its multi-phase flow properties

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Extensive pipeline and railway corridors crossing Canadian peatlands make them vulnerable to hydrocarbon spills, seriously impairing ecosystem health; it is therefore important to be able to forecast hydrocarbon fate and transport within and beyond the peatland. The redistribution of hydrocarbon liquids in groundwater systems are controlled by the multiphase flow characteristics of the aquifer material including capillary pressure-saturation-relative permeability (P_c - S - k_r) relations, which are needed to predict their behavior. However these relations have never been characterized for the hydrocarbon-water phases in peat. To address this, experiments simulating the flow and transport of diesel and water in peat soils were carried out. Immiscible displacement column tests were done in which diesel at the peat surface percolated downward into the saturated peat column, displacing the water phase. The results of these experiments were used in inverse modelling studies in which two-phase relative permeability and capillary pressure relations of peat toward diesel and water were obtained. A peat box experiment was also carried out in which diesel was spilled onto an unsaturated peat layer and tracked, followed by simulated rainfall events to further follow the diesel redistribution. The aim of this experiment was to determine the effect of peat layering and water-table fluctuations on the redistribution of diesel. Processing the data, the quality of diesel redistribution after the spill and the variations of residual diesel saturation in peat vadose zone were determined. The results of these experiments helped fill the data gap present regarding hydrocarbon transport in peat, and can be used in numerical modelling of hydrocarbon transport after a spill accident.

Preferred Platform: Oral Presentation

Student Presenter: Y

Effects of volume change on the unsaturated hydraulic conductivity of Sphagnum moss

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Due to the non-vascular nature of Sphagnum mosses, the capitula (growing surface) of the moss must rely solely on capillary action to receive water from beneath. Moss subsides and swells in accordance with water table levels, an effect called “mire-breathing”, which has been thought to be a self-preservation mechanism, although no systematic studies have been done to demonstrate exactly how volume change affects hydrophysical properties of moss. In this study, the unsaturated hydraulic conductivity (Kunsat) and water content of two different species of Sphagnum moss were measured at different compression rates, up to the maximum of 77%. The findings show that the Kunsat increases by up to an order of magnitude (10x) with compression up to a certain bulk density of the moss, after which higher levels of compression result in lowered unsaturated hydraulic conductivity. This was coupled with an increase in soil water retention with increased compression. The increase of the Kunsat with compression suggests that the mire-breathing effect should be considered a self-preservation mechanism to provide sufficient amount of water to growing moss in times of low water availability.

Preferred Platform: Oral Presentation

Student Presenter: Y

A Statistical Framework for Estimating Monthly Loss of Snow Depth in Southern Canada

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Quantifying the dynamics of snow accumulation and loss has a great importance for understanding the freshwater availability in time and space as well as monitoring the effect of climate change in cold regions. Both physically-based (i.e., energy-balance) and conceptual (i.e. temperature-index) models have been developed for describing the dynamics of snow depth alterations, but there are known deficiencies associated with these models that hinder their applications at the larger scales and/or under data sparse conditions. Here, we develop a statistical approach by fusing a formal predictor selection scheme with Multiple Linear Regression to describe the monthly dynamics of snow depth alteration at 67 stations in Southern Canada. Four model configurations are developed based on combining two rationales for setting up regression models (i.e. direct vs. indirect) and two approaches for input variables selection (local vs. global). Modeling performance is tested rigorously and inter-compared with a frequently-used temperature-index model. The generalization capability of the best statistical model is also investigated to assess the capability of applying statistical models in ungauged sites. Overall, the proposed statistical approach has the potential to effectively describe the monthly alterations in snow depth throughout southern Canada, particularly at western and eastern parts of the country; however, it is shown that the efficiency of statistical models declines in Canadian Prairies and western Ontario, mainly due to the complexity in snow accumulation and loss processes in these regions. In addition, our results show that the parameters of statistical models can be regionalized only by using the three most primary geographic characteristics (e.g. latitude, longitude and altitude), which can provide an opportunity to extend the application of these models in ungauged basins.

Preferred Platform: Oral Presentation

Student Presenter: Y

**Changing Water Temperature in Alpine Basins in the Western Cordillera of Canada:
Historical Variability and Future Projections**

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Although mountainous, mid-latitude catchments characterized by seasonal snow-packs have been identified as exhibiting a heightened vulnerability to warming, few broad-scale studies on long-term stream temperature change have been conducted in the Western Cordillera of Canada. This research assessed the efficacy of a recent and lesser tested approach to quantifying trends in stream temperature through the calculation of stream isotherm shift rates (ISRs) for eight sensitive river basins in this region. In Part 1, ISRs were calculated using modelled water temperature for a historic 60-year period (1950-2010). In Part 2 future stream isotherm shift rates were predicted using CIC projected climate data for 2040-2100 for 6 different Global Climate Models (GCMs). It was found that for seven of the study basins, stream isotherms were moving upstream at rates between 1.85×10^{-3} and 1.81×10^{-2} m/decade in the historic period. The Athabasca River alone demonstrated a cooling trend, with isotherms moving downstream at an average rate of 1.18×10^{-5} m/decade. Stream ISRs for the future period ranged between 2.17×10^{-3} and 7.94×10^{-3} . The results from the historic period analysis are considerably more conservative than those rates estimated in the previous three studies that have applied the same method. The results of the future analysis suggest that while warming trends are expected to continue throughout the current century, only the Athabasca and Liard Rivers demonstrated increases in the rate of isotherm migration upstream. Although perhaps appropriate where data is severely limited, approaches that include additional environmental variables would better capture the expected trends across the varied and diverse landscape of the Western Cordillera.

Preferred Platform: Oral Presentation

Student Presenter: Y

Internet of Things (IoT) Systems and Measurement of Snowpacks

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The Internet of Things (IoT) paradigm involves the networking of ubiquitous measurement systems for data collection. IoT devices can communicate between other devices and servers to transfer data to drive or be assimilated to hydrological models. This talk describes the 4th version of the System for Acoustic Sensing of Snow (SAS4), an IoT electronic device that sends audible sound waves into snow and receives the sound wave reflections using a microphone array. The reflections are digitized and signal processing is used to provide inputs for a mathematical model of sound wave propagation through snow to obtain non-invasive estimates of Snow Water Equivalent (SWE), snow density, depth, liquid water content, temperature, and snow mechanical properties. Improvements to the device include a drastic reduction in its physical device size and the development of a new stable inverse model that provides measurements of snowpack properties using a variety of source signals. An inertial measurement system (IMU) integrated into the SAS4 allows for quantification of device movement when the system takes measurements. An on-board power measurement system allows for power consumption to be tracked and dynamically reduced. On-board GPS measurements provide accurate time clock information and geolocation of snow sampling points. The SAS4 does not require a datalogger, since a real-time clock (RTC) is used to periodically turn the system on when the SAS is used for stationary measurements. Bluetooth and Wi-Fi interfaces allow for communication with other ubiquitous devices. The SAS4 was deployed for testing this winter in the Fortress Mountain Snow Laboratory, Canadian Rockies, Alberta. Additional research, limitations of the system and plans for future deployment in the Global Water Futures programme are discussed.

Preferred Platform: Oral Presentation

Student Presenter: N

Examining Ice Thickness using Simple Temperature Models and RADARSAT-2 in Central Ontario

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Lake ice is becoming a topic of increasing interest due to the impact that it can have on regional climate (lake effect snow) and on under-ice ecological communities. In addition, information on ice thickness is of key importance for communities that rely on stable lake ice cover during the winter months for economic purposes such as ice roads and recreation (snowmobiling). However, ice thickness measurements are underreported for Canada, particularly in temperate latitude areas such as Central Ontario. The primary objectives of this study are i) evaluate the application of previously developed temperature models to estimate lake ice thickness and ii) evaluate the use of RADARSAT-2 imagery to estimate lake ice thickness using linear models. This research was conducted on MacDonald Lake, which located at the Haliburton Forest and Wildlife Reserve Limited in Central Ontario, using temperature and remote sensing data ranging from 2008-2017. Ice thickness measurements were collected both manually and through the use of a Shallow Water Ice Profiler (SWIP) during the winter of 2017. Temperature proved successful at estimating ice thickness until maximum thickness with low RMSE values of 2.3 cm and maximum differences of 5.2 cm when compared to field measurements. Estimates were equally as accurate during thaw with RMSE values of 2 cm. Estimates of ice thickness from RADARSAT-2 backscatter values produced higher RMSE values of 11.6 cm, the relationship observed could be due to volume scattering. Early observations of ice characteristics for Central Ontario ice in 2018 appear to support new ideas on scattering at the ice-water interface within lake ice in Arctic and Subarctic latitudes. Further research is needed to better understand how temperate latitude ice affects backscatter and to explore alternative ways of utilizing remote sensing to detect ice thickness.

Preferred Platform: Oral Presentation

Student Presenter: Y

Atmospheric drivers and spatial and temporal trends in above-freezing winter temperature and associated rainfall in western Canada

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This research identifies trends and atmospheric drivers of winter above-freezing temperatures and associated rainfall in major river basins in western Canada. The availability of freshwater is dependent upon winter snowpack, particularly in mountain headwater regions. Loss of snowpack has been identified as one of the greatest risks to water security and snowmelt during winter has the potential to generate extreme hydrologic events such as river ice break-up and flooding. Snow accumulation and melt are sensitive to fluctuations in air temperature and climatic variability is strongly influenced by large-scale atmospheric circulation. Daily winter (DJFM) synoptic-scale mid-tropospheric circulation patterns from 1949-2012 are classified into 12 dominant types using Self-Organizing Maps (SOM), a cooperative and competitive learning process that clusters and projects data onto a topologically ordered array. Surface climate is evaluated using high-resolution, gridded daily temperature and precipitation data. Days when the mean daily temperature is above 0°C are identified and accumulated melting degree-days (MDD) are calculated for each grid point. Rainfall is identified using a temperature-index precipitation phase equation. Trends are evaluated using the Mann-Kendall non-parametric test. Results reveal widespread significant increasing trends in winter above-freezing temperatures across the study region, and significant, regionally specific increases in rainfall, with considerable spatial variability in the magnitude of these trends. Furthermore, a mid-tropospheric ridge of high pressure over western Canada, associated with a relatively high frequency of above-freezing temperatures and rainfall, has significantly increased over the study period. Results of this research improve our understanding of hydroclimatic variables associated with loss of snowpack and the generation of hydrologic extremes during the winter.

Preferred Platform: Oral Presentation

Student Presenter: Y

The role of basin geometry on snow sensitivity in mountain basins

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Snowmelt contributions to streamflow in mountain basins dominate other runoff sources on both annual and seasonal scales. Increased temperatures and changes in precipitation of future climates will affect both snow accumulation and seasonal runoff timing and magnitude, but the underlying and fundamental role of basin geometry on snow accumulation and melt sensitivity has received little attention. In this work, we examine hypsometric curves from 50 mountain basins in the Canadian Rockies, and develop a model to estimate how hypsometry affects basin-wide snow accumulation and snowmelt runoff timing to climatic change. The model consists of a snowpack based on a prescribed snow accumulation gradient that is placed on the profile for each basin, and a seasonal melt rate based on elevation and energy balance considerations that generates daily snow melt totals for each basins. All basins respond to a prescribed temperature increase of $+2^{\circ}\text{C}$, with reductions in snow accumulation (up to 25%), earlier melt onsets (up to 21 days), and earlier occurrence of the center of snowmelt mass (up to 15 days). With a prescribed temperature increase of $+4^{\circ}\text{C}$ the model shows greater reductions in snow accumulation (up to 40%), earlier melt onsets (up to 50 days) and centers of snowmelt mass (up to 25 days) and further increases in both snowline elevations and steepening of accumulation gradients. The most sensitive basins have the greatest proportion of area at low elevations, whereas the least sensitive basins have the greatest proportion of area at high elevations. This work provides context for ongoing hydrological change, and guidance for both monitoring networks and distributed modelling efforts.

Preferred Platform: Oral Presentation

Student Presenter: N

Climate controls on future hydrologic changes in the sub-arctic Liard River basin

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Freshwater systems in Canada's North are changing rapidly in response to a warming climate, and changing precipitation and snow regime. Under future climate scenarios, the region is projected to experience enhanced warming and amplified moisture fluxes, with the potential to further affect the hydrologic fluxes. In this study, we evaluated potential future hydrologic changes in the Liard River basin in north-western Canada, a basin where the mean annual temperature and precipitation are projected to increase by 6^o C and 20%, respectively (mean of 7 RCP 8.5 GCMs 2071-2100 vs 1976-2005). We employed a statistical downscaling method (n-dimensional multivariate bias correction algorithm) and a hydrologic model (variable infiltration capacity) for projecting CMIP5 GCM based hydrologic changes. The results reveal substantial declines in the magnitude, extent and duration of snow storage, and a shift to earlier snowmelt driven peak flow. These changes are mainly driven by temperature increases, and resulting changes in the magnitude, extent and duration of snow cover. The influence of increased precipitation could be seen in the annual flows, which increase consistently amongst GCMs, RCPs and future periods. Seasonally, the amount of autumn, winter and spring flows are projected to increase while summer flow is projected to decline. Overall, the results reflect complex interactions between temperature and precipitation changes, and substantial changes in the snow and water fluxes that are beyond the range of historical observations in the basin.

Preferred Platform: Oral Presentation

Student Presenter: N

Modelling the fate of nutrients for the lower South Saskatchewan River catchment under future climate change using the WASP model

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The increasing input of nutrients into surface waters under development, changing land use and climate change results in eutrophication, leading to degrading ecosystems and poor water quality. Studies on water quality, particularly water quality modelling, can assist in improved understanding and management of inputs and processes affecting water quality. While most studies have focused on the impacts of climate change on water availability, relatively few have focused on water quality. This study aims to model nutrients within the lower South Saskatchewan River (LSSR), a large and complex system facing multiple human-induced impacts, under future climate change. The heavily-modified flows of the LSSR are fed by water released from Gardiner Dam (Lake Diefenbaker), and water quality is impacted by discharged sewage effluent along the river course. Water quality will be simulated using the Water Quality Analysis Simulation Program (WASP7). This study will build upon several previous studies. In particular, a previous study, using streamflow realisations for the LSSR and Lake Diefenbaker generated from annual expected flow hydrographs under five different annual flow scenarios under climate change, predicted changes to the thermal regime of Lake Diefenbaker and the LSSR using the 2D laterally-averaged CE-QUAL-W2 hydrodynamic and water quality model and the WASP HEAT module, respectively. Another study has used the WASP EUTRO module to simulate nutrients for the LSSR under historical conditions, whereas another has used CE-QUAL-W2 to simulate nutrients for Lake Diefenbaker under climate change conditions. Using the future nutrient simulations for Lake Diefenbaker as a boundary condition, this study will extend the existing WASP EUTRO for the LSSR to investigate nutrients under future climate change.

Preferred Platform: Oral Presentation

Student Presenter: N

How climate change and glacier recession impact a tropical proglacial watershed: Towards a holistic modelling approach

Lauren D Somers, Jeffrey M McKenzie, Bryan Mark, Pablo Lagos, Gene-Hua Crystal Ng,
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In tropical, pro-glacial watersheds, both glacier melt and stored groundwater contribute to streamflow during the dry season when there is little or no precipitation. Though groundwater is understood to be an important part of the proglacial hydrological system, few attempts have been made to include a physically based groundwater component when modeling the effects of climate change and glacier recession. The Shullcas River Watershed is a proglacial mountain watershed in the central Peruvian Andes that receives meltwater from the Huaytapallana Glaciers and provides municipal water for the city of Huancayo. Between 1984 and 2011, the area of the Huaytapallana glaciers decreased by 44 percent, raising questions about future water security. The goal of our study is to use a holistic hydrological model of the Shullcas River Watershed to simulate the impact of climate change and glacier retreat on the magnitude and timing of streamflow and groundwater levels. We use GSFLOW (<https://water.usgs.gov/ogw/gsflo/>), a joint surface and groundwater flow model coupled to a simple glacier melt module to simulate the complete hydrological system of a proglacial catchment in the Peruvian Andes and its sensitivity to a changing climate. A 20 year meteorological record at two weather stations is used to force the model. Calibration and validation are achieved by comparison to our network of 5 stream gages and 5 water table wells dispersed throughout the watershed. Preliminary results indicate that stream discharge would decrease by an average of 14 percent in the absence of glacier melt. The largest relative decreases, around 30 percent, occur during the early rainy season while the smallest relative decreases, around 5 percent, occur in the late rainy season and late dry season. These results demonstrate the importance of including a realistic groundwater flow component when projecting the hydrological impacts of climate change.

Preferred Platform: Oral Presentation

Student Presenter: Y

On the Relationship Between Flood and Contributing Area

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While it is well known that the vast majority of the time only a portion of any watershed contributes runoff to the outlet, this extent is rarely documented. Also, the power-law form of the streamflow and contributing area (Q-Ac) relationship has been known for a half century, but it is uncommon for it to be quantified, and time series of contributing area extensive enough to calculate its frequency distribution are almost non-existent. Data from the Canadian Prairies, where there are extensive estimates of contributing area during the mean annual flood, imply the power law coefficient for any Q-Ac curve is a function of flow magnitude and return period. These data also suggest regional flood frequency curves are a construct of Q-Ac curves from individual basins. This presentation will discuss research that attempted to reproduce the Q-Ac curves for the La Salle River Watershed with a semi-distributed numerical hydrological model; MESH-PDMROF. The model simulated streamflow reasonably well (Nash Sutcliffe values = 0.62) compared to published examples of comparable models applied in the region. Estimates of the coefficient and exponent of the Q-Ac power law function ranged from 0.08 – 0.14 and 0.9 - 1.12, respectively. These exponent values were lower than those of regional flood frequency curves and support the theory that regional flood frequency curves are a construct of Q-Ac curves. However, simulations of the area contributing to the mean annual flood were much lower (0.3) than those derived from independent topographic analysis (0.9) described in earlier literature. This uncertainty was extended across the flood frequency distribution, and may be too large to definitively verify the study hypothesis.

Preferred Platform: Oral Presentation

Student Presenter: N

Modelling the effect of water level conditions and return flow periods on resuspension of bottom sediment in the Glenmore Reservoir: Implications for reservoir management

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The accumulation of deposited cohesive sediment in reservoirs can increase phosphorus release to the water column and increase the risk of algal blooms and subsequent taste and odor events. Moreover, the resuspension of deposited materials at higher flow conditions can increase levels of sediment-associated pathogens which can pose treatment challenges. Accordingly, the ability to assess reservoir conditions that cause either the deposition or resuspension of sediment is important for the provision of safe drinking water. To evaluate the effect of operating water level conditions and return flow periods on sediment resuspension, a suspended sediment survey was conducted at the Elbow River inflow and at multiple transects and depth profiles across the Glenmore Reservoir. The flow field and suspended sediment transport in the reservoir were calculated using two US Army Corps of Engineers reservoir models RMA2 (a two-dimensional depth averaged finite-element hydrodynamic model) and RMA4 (a two-dimensional depth-averaged finite-element sediment transport and water quality model) respectively. From the computed flow field, bed shear stresses in the reservoir were calculated and were compared with the critical bed shear stress for the erosion of the fine sediment measured using a rotating circular flume to assess the erodibility of the fine sediment deposits in the reservoir. The potential erodibility of the fine sediment in the reservoir was estimated for a range of river discharges (2, 5, 10, 20, 50, 100, 500 return periods) and four operational water levels (1.5m above crest, crest, 1.5 m below crest and 3.0m below crest). The results show that sediment resuspension rates for a flow with given return period increases with decreasing water level in the reservoir. The combined effect of decreasing water level and < 5 year return flow period is most pronounced in the shallow outer basin where resuspension rates are the highest. Resuspension in the deeper inner basin near the water intake can occur at ~20 year return flow periods. Increased turbidity levels resulting from these flow conditions will increase treatment costs due to increased use of coagulant and related waste removal.

Preferred platform: Oral presentation

Student presentation: No

A new modular framework for modelling unsaturated soil hydraulic properties over the full moisture range

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Effective models describing the soil hydraulic properties (SHP) are essential for numerical simulations of transient water fluxes in variably saturated soils with the Richards equation as process model. A prominent example of application is for transient models of coupled water-agrochemical (nitrogen, pesticide) processes in the soil-plant-atmosphere continuum. During the past four decades, a plethora of SHP models has been developed. Recently, it has been acknowledged that the SHP functions have to represent the full moisture range, i.e. from saturated to completely dry soils. To achieve this, we further developed a model for the water retention curve (WRC) which is given as a sum of any given parametric capillary saturation function and a new model for the non-capillary saturation function. This model can be directly computed from any selected capillary saturation function. With it, a continuously differentiable, flexible, and physically coherent representation of the WRC is achieved. In a modular and hierarchical framework, the expressions for the capillary and non-capillary saturation function are then used to calculate the respective hydraulic conductivity curves (HCC). We show that this leads to consistent descriptions of measured HCC data, including the often observed change of slope beyond $pF = 2$. This is achieved by adopting Mualem's integral for the capillary part of the HCC only and calculating the non-capillary HCC directly from the new non-capillary saturation function. The SHP model framework describes both WRC and HCC adequately and coherently. Compared to the classical van Genuchten-Mualem approach, it requires only one additional model parameter. We demonstrate the suitability of the new SHP framework by describing measured WRC and HCC data of soil samples with a wide range of textures and origins at a wide range of moisture states.

Preferred Platform: Oral Presentation

Student Presenter: No

Hydrologic and Water Isotope Characterization of a Regulated Canadian Shield River Basin

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Water isotope surveys have increasingly been integrated into river basins studies, but few have used them to evaluate impact of hydropower regulation. This study applies hydrologic and water isotope survey approaches to a Canadian shield river basin with both regulated and natural flows. Historical streamflow records were used to evaluate influence of three hydroelectric reservoirs and unregulated portions of the basin on downstream flows, and changes in water level management implemented after an extreme flood year (1979). In 2013, water isotope surveys of surface and source waters (e.g. rainfall, groundwater, snowmelt) were conducted to examine spatial and temporal variation in contributions to river flow. Seasonal changes in relative groundwater contribution were assessed using an isotope mass balance approach. Within the basin, two regulated reservoirs exhibited inverted hydrographs with augmented winter flows, while a third exhibited a hydrograph dominated by spring snowmelt. In 2013, spatial variation in rain-on-snow and air temperatures resulted in a critical lag in snowmelt initiation in the southern and northern portions of the basin resulting in a dispersed, double peak spring hydrograph, contrasting with 1979 when a combination of rain-on-snow and coincident snowmelt led to the highest flood on record. While eastern basin reservoirs become seasonally enriched in $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values, unregulated western basin flows remain less variable due to groundwater driven baseflow with increasing influence downstream. Combined analysis of historical streamflow (e.g. flood of 1979, drought of 2010) and the 2013 water isotope surveys illustrate extreme meteorological conditions that current management activities are unable to prevent.

Preferred Platform: Oral Presentation

Student Presenter: N

Validating the isotopic reconstruction of winter streamflow using ice cores in the Athabasca River, Alberta, Canada

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In cold regions, ice creates an archive of hydrologic conditions, captured moving down the water column as ice grows, preserving the isotopic signature of streamflow, offset by the fractionation of the water to ice. This archive, captured in the river ice stratigraphy, makes ice cores ideal for reconstructing streamflow. Though minimally studied, this methodology can provide insight on the variability of streamflow, determine when shifts in source waters have occurred and allow the contribution of source waters to be quantified. In comparison to experimentally determined values for fractionation, studies in the field have had accurate results but have all assumed the fractionation from water to ice was constant throughout the ice on period. Preliminary research on this method in 1999 and 2002 recommended a complete season of streamflow data be collected in conjunction with ice cores to verify that the fractionation of water to ice is consistent throughout the ice on period. In this presentation I will use the Athabasca River, a large river in Northern, Alberta, Canada and the McLeod River, a tributary of the Athabasca River, to discuss the accuracy of reconstructing streamflow using river ice stratigraphy, verified using routine streamflow samples over the ice on period. Additionally, I will identify large changes in source water contribution and the potential events that lead to the availability of these source waters. For this methodology, dates were extracted from the ice using the Stefan formula, an ice growth model that utilizes accumulated freezing degree days. The calculated fractionation ($\delta^{18}\text{O}_{\text{ice}} = 1.0029 \delta^{18}\text{O}_{\text{water}} + 2.95$ and $\delta^2\text{H}_{\text{ice}} = 1.0184 \delta^2\text{H}_{\text{water}} + 18.45$) was compatible with the existing literature. Lastly, streamflow and reconstruction of streamflow comparisons as well as testing the assumption of constant water to ice fractionation demonstrated minimal differences, taking into consideration the margin of error caused by instrumental precision.

Preferred Platform: Oral Presentation

Student Presenter: Y

CGU_H_01

Success and failure in the St. Elias Mountains [Invited]

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Field work offers ample opportunity for research failures, given the conspiracy of uncontrolled variables related to equipment, logistics, weather, terrain, changing landscapes, injuries and other human factors, and acts of God and God's creatures. The highlight of my professional career thus far has been the establishment of a field-based research program in the St. Elias Mountains of southwest Yukon to study the dynamics, hydrology and climate-response of glaciers. Over its 12 years, this program has nucleated collaborations, been the source of numerous research projects and student theses and has produced a few unexpected discoveries. The highs have been high, but the lows can sometimes be low personally, professionally and in other unexpected ways. I will touch on examples of the challenges that have arisen from human and natural causes, and reflect on how they have impacted the research and the way I approach it. Collectively, these successes and failures highlight the importance of being prepared and having backup plans, distributing research risk (e.g. across methodologies, across field locations, through time), undertaking pilot projects, prioritizing in the short term while playing the long game and developing collaborations.

Preferred Platform: Oral Presentation

Student Presenter: N

Illuminating the unseen: resolving how reflection impacts stream temperature observations from time-lapse, ground-based IR cameras [Invited]

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Rapid advances in infrared (IR) camera technology have made it possible to observe stream temperatures remotely with very high spatial resolution at increasingly low cost. The result has been proliferation of applications of IR cameras to detect fine-scale changes in stream temperatures caused by groundwater inflows, storm drain outfalls, and more. Time-lapse, ground based IR photography has the added potential of generating high resolution temperature observations with time, as well as in space, but efficient and effective correction of time-lapse IR images remains a challenge. We deployed a high-definition thermal IR camera on the wall of a proglacial valley, 50 to 100 m above the valley floor, and collected time-lapse images every 10 minutes over periods of 4 to 5 days during two different field seasons. The images provide continuous temperature observations in a proglacial stream at ~10-50 cm spatial resolution, but the remotely sensed temperatures deviate substantially from temperatures recorded by sensors at control points. Analytical methods derived from the literature were used to correct IR temperatures by incorporating the effects of atmospheric transmissivity and water emissivity, but do not improve the accuracy of the remotely sensed temperatures. Although this result initially suggested time-lapse ground based IR photography was a failure, our findings motivated advances in how we correct time lapse images to accurately measure water temperatures. Careful scrutiny of the analytical approach reveals its failure to account for error introduced by (a) the low emissivity of water at low camera viewing angles and (b) the influence of reflected temperatures from the surrounding environment, which can be highly variable. We propose a simpler, empirical approach to correct time-lapse IR images that uses observed errors at control points to make offset corrections through time.

Preferred Platform: Oral Presentation

Student Presenter: N

On measures of water storage and release dynamics: comparative assessment in seasonally cold and dry watersheds

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The mechanisms via which watersheds store and release water over a range of timescales are important to understand as they relate to the persistence of nutrients and contaminants and their timing of release into streams, long-term water availability, and resilience of hydrosystems to land use and climate change. Several parameters have been deemed adequate to infer water storage and release dynamics in watersheds, notably with studies focusing on the quantification of “new water” fractions (e.g., proportion of streamflow fed by the most recent precipitation), young water fractions (i.e., proportion of streamwater with age of three months or less), mean response times (i.e., average speeds with which a watershed responds to precipitation) and mean transit times (i.e., average travel times of conservative water tracer). However, to date, few studies have confronted the information provided by two or more of these parameters quantified for a given site. Here such a comparison was made using a system of nested Prairie watersheds (southcentral Manitoba, Canada). Stable water isotopes and hydrometric data were frequently collected across eight different outlets during one dry year and one wet year and used to evaluate a range of storage-and-release measures. Results show that short-term wetness conditions greatly influence “new water” fractions, which decreased progressively from the freshet to the summer season. Longer-term (i.e., annual) wetness conditions also exerted control over mean response times and mean transit times, which were significantly longer in the drier year. While some of the measures were in agreement with one another, regarding the ranking of the study sites from slower to faster storage-release dynamics, others were not. This work will therefore provide recommendations regarding the storage-release measures that are the most appropriate and straightforward to use in seasonally cold and dry watersheds.

Preferred Platform: Poster Presentation

Student Presenter: Y

Isotope Hydrology of the Muskoka River Watershed, Central Ontario, Canada

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Canadian Shield watersheds in Ontario are under increasing pressure from cumulative effects (climate change, hydropower, nearshore development, acidification) on water quality and quantity. Despite these pressures, use and development of investigatory tools in Shield watersheds like distributed hydrologic and nonpoint source pollution models and watershed-scale stable water isotope datasets are limited. To address such limitations in the Muskoka River watershed located in Central Ontario, stable water isotope characterization is underway in support of future hydrologic and water quality modeling. Preliminary isotope and hydrologic characterization of the watershed, a highly managed river system is presented. Surface water isotope ($\delta^{18}\text{O}$ and $\delta^2\text{H}$) were collected monthly (April 2015-Nov 2016) at ten river locations with discharge available at a subset of locations through government sources. Source water (groundwater, precipitation and snowmelt) samples along with meteorological data are available within the watershed at select locations. Water isotopes are well suited to identifying the influence of evaporatively enriched surface waters compared to regional groundwater contributions to streamflow. While results illustrate a trend of heavier isotope depletion in summer baseflow with downstream distance in headwater rivers, this disappears within the Lower Muskoka sub-watershed. Slopes of $\delta^{18}\text{O}$ and $\delta^2\text{H}$ for individual sampling location ranging from 4.14 to 5.79 indicate variable influence of evaporation across river locations. The period of record (April 2015-2016) illustrates the well-defined seasonal variation in water isotopes in river flow with varying influences of snowmelt, groundwater and summertime evaporative enrichment. River isotope values observed during the flood conditions of spring 2016 suggest an influence of dam management activities, such as the release of isotopically enriched winter-over storage.

Preferred Platform: Poster Presentation

Student Presenter: Y

A $\delta^{18}\text{O}$ and $\delta^2\text{H}$ stable isotope analysis investigating alpine forest water sources under varying environmental conditions and stressors

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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. Study sites located at Fortress Mountain in Kananaskis, Alberta are composed of coniferous tree stands of *Abies lasiocarpa* and *Picea engelmannii*. This study is a continuation of an alpine forest water use study focussed on understanding important water sources and stressors during variable growing season conditions. In addition to tree transpiration collected by non-invasive stem-heat balance systems and evapotranspiration collected by eddy covariance method, $\delta^{18}\text{O}$ and $\delta^2\text{H}$ stable isotope studies were also collected. Samples of tree tissue (twigs with needles removed) from the top, middle and bottom of the tree were collected in addition to a sample size of eight trees, four from each species, of varying size and classes. Soil samples were taken at the foot of each sampled tree to account for moisture retained in the soils. Precipitation, groundwater and snowmelt were also sampled if they were available. In addition to the tree tissue, these water sources were collected over three main sampling periods, pre, during and post growing season. Processing of the organic materials (tree tissue, soil) is being done by azeotropic distillation at the University of Waterloo Environmental Isotope Laboratory. Anticipated results are expected to show similar trends to the hydrometric analysis, with trees sourcing their water pre season from snow melt and the remaining points of the year from soil moisture via precipitation inputs. 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.

Preferred Platform: Poster Presentation

Student Presenter: Y

Extending a General Hydrologic Modelling Framework to TIN-Discretized Landscapes

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Catchment topography, including the distribution of surface slope and aspect, is an important characteristic of catchments which can have a major influence on the spatial and temporal hydrological response of a catchment. Catchment topography influences processes like snow melt and surface or near-surface runoff, which can be important factors in predicting the quantity and timing of stream flow. Distributed models attempt to capture the topographic influence of a catchment through the use of terrain data. Digital elevation models (DEMs) are one form of terrain data that is widely available at high resolution. However, the computational cost required in discretizing at the resolution of gridded digital elevation models is high and a tradeoff is often made with the resolution of data, leading to inaccuracies that propagate through the model. Triangulated irregular networks (TIN) are an alternative form of terrain representation which can be used to represent the spatial domain of a catchment. TIN data allows for the resolution of topographic features like slope and aspect to be maintained while reducing the computational requirements when compared to gridded digital elevation models. This work presents the development of a distributed triangular irregular network model using a flexible hydrologic modelling framework (Raven), which was originally devised to use subbasin or grid-cell watershed discretization. A simple and efficient method of determining the stream network from a TIN is outlined alongside a straightforward methodology for coupling the stream network with the routing capabilities of Raven. TIN-discretized model output is compared to results from a more conventional lumped HRU-discretized model using an application from the Canadian Rockies.

Preferred Platform: Poster Presentation

Student Presenter: Y

Assessing basin storage: a combined hydrometric and isotopic approach

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The ability of a drainage basin to store and release precipitation inputs may mediate its sensitivity to climate and land cover change. However, there is no agreement on the best means of quantifying basin storage. We present the results of a combined hydrometric – isotopic approach to characterizing inter-basin differences in storage for drainage basins on the Oak Ridges Moraine in southern Ontario. Streamflow-based indicators of storage included the baseflow fraction of total streamflow (baseflow index) and the slope of basin flow duration curves. The ratio of the standard deviation of the streamflow isotopic signature relative to that of precipitation was determined for each basin, based on samples taken from Fall 2016 to the end of 2017. Previous work has shown this ratio to be inversely related to mean water transit time, such that smaller ratios imply greater basin storage. Isotopic standard deviation ratios were inversely related to basin baseflow index values and were positively related to the slope of the flow duration curve, indicating that basins with relatively stable flow regimes that were dominated by baseflow contributions had relatively long mean water transit times. Headwaters of such basins had extensive outcropping of glaciofluvial sands and gravel deposits that promote groundwater recharge. Future work will explore the role of such factors as topography and land cover in explaining inter-basin differences in these hydrometric and isotopic metrics of basin storage.

Preferred Platform: Poster Presentation

Student Presenter: Y

An investigation of sea ice, snow cover, and snow melt conditions between 2000 – 2017 on Bathurst Island, Nunavut, Canada

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Increasing Arctic temperatures have resulted in reductions in sea ice extent and snow cover duration, as well as earlier melt onset. As most studies focus on assessing components of the cryosphere at the pan-Arctic scale, detailed localized investigations are limited. The purpose of this study is to investigate sea ice, snow cover, and snow melt conditions between 2000 – 2017 on Bathurst Island, NU. IMS and 8-day MODIS Snow and Ice products are used to examine changes in sea ice and snow cover and are compared to ERA-Interim gridded climate data and weather station observations from Polar Bear Pass, NU. While no significant trends in annual and seasonal temperatures from 2000 – 2017 were found, results highlight spatial patterns across the island. Sea ice break-up (freeze-onset) occurs earlier (later) south-west of Bathurst Island, and snowmelt (snowfall accumulation) occurs earlier (later) in the southern region of the island. This corresponds with slightly higher temperatures across the southern portion of the island, compared to the northern regions where seasonal sea ice retreat occurs only occasionally. Sea ice trend analysis highlights significant regional differences in sea ice during the melt/freeze seasons from 2004 – 2017. Results show that sea ice break-up begins earlier east of Bathurst Island and north of Cornwallis Island through the Penny Strait, while sea ice south-west of Bathurst Island shows trends towards later water clear of ice dates. Regions south and south-west of Bathurst Island show slightly earlier freeze onset, with most of the region showing a 0 – 1-day change. Understanding the interactions of sea ice and snow cover in the context of a warming climate is essential for identifying patterns of variability and change and can be used to understand changes to the global climate system, effects on terrestrial and marine ecosystems, and to reduce the vulnerability of northern residents to risks associated with climate change.

Preferred Platform: Poster Presentation

Student Presenter: Y

Suspended Sediment and Associated PACs in the Ells and Steepbank Tributaries of the Lower Athabasca River: Spatial and Temporal Trends

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Within Alberta's Athabasca Oil Sands Region, many of the Athabasca River tributaries incise the bitumen-bearing McMurray Formation (MF) resulting in erosion, transport and deposition of naturally-occurring bitumen (oil) containing sediment. In addition to this natural source of Polycyclic Aromatic Compounds (PACs) to the aquatic environment, other potential sources include atmospheric deposition of PACs resulting from stack emissions, dust from the mining operations, and forest fires. As part of Environment and Climate Change Canada's (ECCC's) ongoing monitoring and research in the oil sands region, an investigation was undertaken to assess the temporal and spatial trends in tributary suspended sediment/PAC transport on two of the tributaries, the Ells (EL) and Steepbank (STB) Rivers, and to determine using various PAC homologs whether the source is of a petrogenic and/or pyrogenic origin. This poster presentation provides results that show: (i) there was a longitudinal increase in PAC concentrations from upstream to downstream regardless of time-of-year; (ii) loads were substantially increased during high flow periods when the erosive forces are the greatest and the overland flow contribution is high; (iii) EL possessed higher loads of PACs than STB; (iv) double plot PACs ratios suggest that the PAC sources are different between the two rivers (i.e. bitumen signatures vary spatially within the deposit), however the weathering processes were similar; and (iv) plots of the various homologs of PACs generally suggested petrogenic origins. However, several PAC ratios suggested that both the parent material and the suspended sediment can also have pyrogenic characteristics. Additional investigation is required to further our understanding of the source and type of PACs (petrogenic vs. pyrogenic) associated with tributary suspended sediment/contaminant transport and fate.

Preferred Platform: Poster Presentation

Student Presenter: N

Modelling Sphagnum moss: Determining the appropriate model to simulate field scale soil moisture dynamics

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Sphagnum mosses are non-vascular species that rely on capillary forces to retain soil moisture at the top of the profile for growth in the capitula to occur. After peat harvesting operation cease a quick return of moss is desirable for restoration or Sphagnum fibre farming. Hydrological modelling is a tool that can be used to assess management practices and risk thresholds.

Although van Genuchten-Mualem (VGM) parameters have been characterized for mosses, none of them have been verified at the field scale. Previous research has identified additional process beyond the scope of the VGM, as such the van Genuchten-Mualem model with hysteresis (VGMH) and Durner, dual van Genuchten- Mualem (DVGM) models have also been proposed to accurately simulate unsaturated processes. The present study aims to assess which model is able to best describe observed soil moisture -2.5 and -7.5 cm in a 10 cm regenerated Sphagnum moss profile. Global parameter fitting with Hydrus 1D was done with inverse modelling to estimate the required parameters for all models. Simulated soil moisture for each model was compared to field observations to assess model performance. Preliminary model results suggest the simplest model best represents the field conditions, despite discrepancies in soil moisture during precipitation events. The results of this study will be used to understand hydrological risk and optimization thresholds for peatland restoration and Sphagnum fibre farming.

Preferred Platform: Poster Presentation

Student Presenter: Y

Joint variability of precipitation and temperature over Canada

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Hydrological extreme events, such as rain-on-snow induced flooding, are commonly caused by the joint behavior of multiple variables, in particular temperature and precipitation. Temporal changes in their joint variability, as well as their individual nonstationary behavior can increase the intensity and frequency of catastrophic events. Increases in the occurrence of extreme precipitation in unusually warm days during winter or early spring, for example, can result in more frequent and unprecedented flood events. The objective of this study is to investigate the observed and simulated dependency structures between temperature and precipitation in Canada at both daily and sub-daily time scales. Nonstationary marginal distributions of these components as well as their time-varying dependencies are analyzed using Copula, based on station observations and a large suite of CanRCM4 simulations for 1970-2010. Results show that the rates of change and degrees of dependencies between temperature and precipitation vary based on the geographic locations of stations. In addition, interdependence between the two components changes in wet and dry seasons. Temporal analyses show increases in wetter and warmer conditions in several regions in Canada.

Preferred Platform: Poster Presentation

Student Presenter: Y

Hydroclimatic controls on runoff generation in a tile drained, near-level vertisolic clay soil-landscape in the cold climate of Western Canada

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Agricultural tile drainage has the potential to exacerbate water quality issues such as eutrophication, depending on the degree of preferential connectivity between tiles and the surface. The expansion of agricultural tile drainage in the Northern Great Plains of North America is controversial due to persistent water quality problems. Runoff-generating mechanisms in tile drained landscapes have not been investigated in the clay-rich vertisolic soils of the Red River Valley. This study evaluated the role of climate drivers on the activation of overland (OF) and tile (TF) flow and groundwater response (GW) on tiled and non-tiled working farm fields in Southern Manitoba, Canada. Twenty-three hydrological events were monitored in 2015 and 2016 open water periods (April-October), and the time delays between rainfall inputs and the response of various flow pathways (OF, TF, GW) was assessed. Most often, OF was activated prior to TF and GW in the tiled field, and, the field wetted up from the top down. This was comparable to the OF activation in the non-tiled field which indicates the installation of tiles did not affect the early activation of OF in this landscape. Although vertisolic soils are often prone to vertical preferential flow via desiccation cracks and often showcase quasi-simultaneous OF and TF activation, they were uncommon at our site and only observed in summer (2 out of 12 summer thunderstorms). More rapid responses occurred with greater rainfall intensity; however, tile and groundwater responses in spring were also hastened under wetter antecedent conditions. This work demonstrates that flow activation varies temporally, where soil saturation may occur from the bottom up via rising water tables, or from the top down via infiltration and wetting fronts. Such 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.

Preferred Platform: Poster Presentation

Student Presenter: Y

Changes in extreme daily temperature and precipitation over Western Canada based on a large ensemble of climate change simulations

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Canada is warming at a higher rate compared to the global average, causing possible increases in the intensity and frequency of extreme temperature and precipitation that can threaten existing infrastructure. We analyze these impacts over the Fraser, Peace, Columbia and Campbell River basins in Western Canada using eight CLIMDEX indices: Growing Season Length (GSL), maximum temperature (TXx), minimum Temperature (TNn), number of days with precipitation greater than 10mm (precip10), monthly maximum consecutive 5-day precipitation (RX5day), simple precipitation intensity index (SDII), total amount of precipitation exceeding the 95th percentile of the climatological distribution for wet day (wet days mean $RR \geq 1.0\text{mm}$) (R95pTOT), and maximum number of consecutive dry days (dry days mean $RR < 1\text{mm}$) (CDD). Historical (1981-2010) and projected (2060-2089) values of these indices are assessed using the observed gridded data generated at the Pacific Climate Impacts Consortium ($1/16^\circ$ resolution), a large ensemble of 50 climate simulations based on the CanESM2 model (CanESM2-LE), and seven General Circulation Models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5): ACCESS1-0, ACCESS1-3, CanESM2, CCSM4, CNRM-CM5, HadGEM2-ES, and MPI-ESM-LR. All climate model simulations are downscaled using the Bias Correction/Constructed Analogues with Quantile mapping reordering approach under the Representative Concentration Pathway (RCP) 8.5 emission scenario. Results show that the intensity and frequency of extreme temperature and precipitation are projected to increase in western Canada. In addition, the uncertainties arising from internal climate variability (represented by CanESM-LE) are significant and should be taken into consideration more in future climate change studies.

Preferred Platform: Poster Presentation

Student Presenter: Y

Investigating the effects of stream inflows on central Ontario lake ice

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A significant component of the Canadian terrestrial cryosphere is lake ice. Recent studies suggest some striking changes to lake ice phenology: early ice break-up, and later freeze-up. However, since the 1990s, very limited amount of ground-based lake ice observations have been conducted on lake ice in central Ontario. Near-shore ice cover formation can be delayed due to water turbulence or due to a difference in temperature caused by stream/river inflows. This study investigates the point if/when lake inflow ceases and ice cover forms; explores the temperature difference between the inflow and lake water; and utilizing this information, models ice thickness in the inflow regions using the Canadian Lake Ice Model (CLIMo). A network of waterproof temperature sensors (HOBO pendant loggers, attached to perforated ABS pipes with a cement base) were submerged 1 - 4 m below the water level, and Reconyx outdoor digital cameras were installed around the inflows to collect time lapse imagery at Clear Lake and MacDonald Lake (Cameras only for MacDonald Lake 2017/18 season), located in the Haliburton Forest and Wildlife Reserve (Haliburton, ON). Vertical temperature profiles were used to assess the effects of the inflow on the ice thickness within the inflow regions. The field site was monitored from mid-fall to spring break-up in order to closely assess the timing of the lake ice formation and decay. Results indicate thinner or no ice, and an earlier spring ice off at the inflow regions compared to other regions of the lake. Preliminary model results suggest an extended ice cover compared to the observations as the model in its original form did not account for additional heat inputs from the inflows. Modifications to CLIMo are explored in order to more accurately simulate the lake inflow regions.

Preferred Platform: Poster Presentation

Student Presenter: Y

**Assessing Historical Runoff Changes in Three Cold Regions Rivers in Western Canada
with Hydroelectric Power Generation Potential**

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Several flow regimes in Canada have already been altered and/or identified for future development to meet hydropower needs. There is a need for new development projects to carry out an assessment of environmental flow needs in the context of a changing climate in order to preserve the natural function of river and floodplain ecosystems into the future. Environmental flow needs and climate change assessments frameworks incorporate a range of ecologically-relevant hydrological variables. However, when applied in cold regions, these approaches have largely ignored the influence of winter ice cover and the spring freshet on hydrological regimes - key components of river systems in cold regions with direct effects on water quality, aquatic habitat and ecology. We identified several ecologically-relevant hydrological measures, pairing these with established metrics for incorporation into an enhanced suite of indicators specifically designed for cold regions. The goal of this paper is two-fold: 1) Present the Cold-regions Hydrological Indicators of Change (CHIC), which can provide the basis for the assessment of ecological flow needs and climate change assessments in cold-region river ecosystems; 2) Apply the CHIC approach to a) assess historical climate change and flow regulation changes to already regulated Peace River flow regime, and b) assess historical flow regimes of the adjacent Athabasca and Liard Rivers where hydroelectric dams have been proposed on the river mainstem.

Preferred Platform: Poster Presentation

Student Presenter: N

Climate change and sensitivity in a high alpine catchment

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Snowpacks in the Canadian Rockies provide large amounts of freshwater for downstream environmental and socio-economic demands. Modifications to the snowpack storage can have severe implications for these uses. Mountain streamflow and snow accumulation and ablation have been studied in Europe and in the Canadian Rockies; however, there is a lack of understanding of how hydrological processes in the complex terrain of high alpine catchments in the Canadian Rockies will respond to climatic changes. Helen Creek Research Basin is a small, high elevation alpine basin (~2.5 km², 2600 m mean elevation) in the Canadian Rockies with complex terrain, a relict rock glacier and an alpine lake. The Cold Regions Hydrological Modelling platform was used to create an alpine hydrological model to simulate the dominant hydrological processes of this basin, in order to understand the recent hydrological regime. The model was constructed and parameterized based on the current understanding of alpine hydrology, field research in the basin, and studies in the surrounding regions. Observations taken during a 2-year control period were used to evaluate model predictions of snow accumulation, ablation and streamflow. The model adequately simulated snowpacks and streamflow, and provided a diagnosis of the processes controlling these regimes. The results help to understand the hydrology of alpine basins in the Canadian Rockies. In a future study, this model will be used to evaluate how the hydrological processes are evolving under a changing climate in this catchment.

Preferred Platform: Poster Presentation

Student Presenter: Y

Modelling Lake Ice Melt-onset and Breakup Dates from Southern Ontario to the High Arctic

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Lake ice research demonstrates that ice phenology is sensitive to climate variability, with a strong relationship to both air temperature and large scale atmospheric patterns. However, further investigation is required to understand the larger spatial extent of changes to lake ice. Lake ice models can be used to study the latitudinal differences of current and projected change in ice covered environments. The Canadian Lake Ice Model (CLIMo) is a well-tested one-dimensional thermodynamic freshwater ice cover model that has been successful in simulating Arctic and sub Arctic lake ice cover. This study presents a latitudinal comparison of melt rates (using ice thickness) and breakup (BU) timing. The study sites are in the High Arctic (Small Lake and Resolute Lake, Resolute, NU) and temperate region (MacDonald Lake and Clear Lake, Haliburton, ON). Melt onset and BU are modelled using meteorological data (obtained from Environment Canada for the Resolute lakes and a nearshore weather station for MacDonald Lake); daily mean values of air temperature, relative humidity, cloud amount, wind speed, snow depth, and snow density). Simulations are validated using a Shallow Water Ice Profiler (SWIP), camera imagery, and ice records from the Canadian Ice Database (CID). Initial simulations for Haliburton show that the melt rate and subsequent BU timing are under predicted, which is likely due to the different ice composition typical in the temperate region (more white ice than develops on the High Arctic lakes). Field measurements of albedo indicate that during melt periods the albedo drops to ~ 0.28 . Adjusting albedo however, does not account for snow ice (~ 40 cm) growth or decay in Haliburton, ON. To better represent temperate region ice cover using CLIMo, an adjustment of the surface properties of the ice cover during melt is explored.

Preferred Platform: Poster Presentation

Student Presenter: Y

Comparison of rainfall-runoff relationships across scales and environments

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Hyetograph-hydrograph analysis, notably following manual rainfall-runoff event delineation, is commonly performed to establish characteristics of rainfall-runoff relationships, in terms of timing (e.g., response lag) and magnitude (e.g., runoff ratio). To date, manual event delineation proved to be effort-intensive, therefore impeding comparative studies across scales and environments. The goal of this study was to use a new automated event delineation tool to conduct a large comparative study of event-based rainfall-runoff relationships across one hillslope and 20 catchments that vary in scale (0.01 – 145 km²), climate, topography and geology. They were selected from seven geographic regions: the Panola Mountain Research Watershed (GA, USA), the HJ Andrew's Experimental Forest (OR, USA), the Catfish Creek Watershed (MB, Canada), the Experimental Lakes Area (ON, Canada), the Hermine catchment (QC, Canada), the Tarrawarra catchment (Australia) and the Mahurangi catchment (New Zealand). Over 2100 rainfall-runoff events were delineated using the MATLAB toolbox HydRun to derive event-specific hyetograph-hydrograph parameters, surrogate measures of antecedent moisture conditions and evapotranspiration. Principal component analysis and variation partitioning were used to evaluate which parameters are most important in explaining variability among events for each site. Preliminary results show markedly different values of hyetograph-hydrograph parameters across regions, reflecting the different physical and climatic conditions prevailing in those regions. Inter-event variability appears to be driven by response timing parameters at some sites and response magnitude parameters at other sites, hinting at regionally distinct response types. Future analyses will include additional rainfall-runoff response characteristics, specifically characteristics that capture nonlinearities and thresholds in rainfall-runoff relationships.

Preferred Platform: Poster Presentation

Student Presenter: Y

Hydrological response of a sandur-wetland to seasonal and episodic events, South Iceland

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Iceland is a geothermally active island with sharp contrasts in climate and geography. Here, a 2.5 km stretch of a proglacial river neighboring an inhabited wetland, which has been losing ground to the sandur, was monitored between 1 September, 2015 to 1 September, 2016 and in greater detail between June – August, 2016. An understanding of the hydrological regime at this interface is critical for farmers and local residents who live within this dynamic and quickly shifting landscape. Water wells along transects monitored the water table response across this sandur-wetland landscape which is usually found near the surface. Geomorphic and climatic data were also collected at this site in order to better understand the sandur's and wetland's hydrological response to both seasonal and episodic weather events which occur here, such as reoccurring glacial outburst floods, sandstorms and severe or prolonged rainfall episodes. On October 4th 2015, a glacial outburst flood coinciding with a period of high rainfall caused flooding over much of the sandur. Furthermore, in Spring 2016, water levels in the wetland closest to the farm were found to respond in similar fashion to water levels in the sandur during a sandstorm induced glacial outburst flood. Changes in water level barely fluctuated in the downstream wetland farthest from the farm. Groundwater discharge from the sandur to the wetland occurred on a continuous basis throughout September 2015 to September 2016 with increasing rates during the passage of episodic events. High hydraulic conductivity estimates of the material which make up the bulk of the sandur and berms, in addition to the intricate network of macropores found in the vicinity, demonstrate a complex porous sandur-wetland interface where transfers of water are uninterrupted, and where inputs of water are generally greater than outputs.

Preferred Platform: Poster Presentation

Student Presenter: Y

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

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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.

Preferred Platform: Poster Presentation

Student Presenter: Y

Modelling Seasonal Ground Ice and Evapotranspiration in a Western Boreal Plains Peatland using the Cold Regions Hydrological Model (CRHM)

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The cold regions hydrological model (CRHM) has been used across various cold region climates, ranging from alpine and glaciers to arctic tundra and permafrost environments. In Canada though, there are many other cold region climates that are neither alpine in nature, nor exhibit permafrost. The Western Boreal plains in northern Alberta is one such cold region climate, that is covered in extensive organic peatlands and mineral uplands. These peatlands are subjected to annual freeze/thaw cycles and can form extensive ice layers in the thicker organic soils, which has major implications for the spring freshet and early growing season surface energy balance. Currently, CRHM models an ice layer as permafrost and only considers energy inputs from the surface. In seasonally frozen soils, this setup ignores the influence of bi-directional thaw where an unfrozen layer beneath the ice can transfer heat energy leading to quicker thaw and subsequent melt season. This study proposes using the XG, a modified Stefan equation and running it from above and below the ice layer in order to simulate a more realistic thaw. The successful implementation of this approach will expand the use of CRHM, and allow for a more accurate simulation of seasonally frozen peatland soils. This poster will outline the parametrization of the CRHM model within a Western Boreal Plains Peatland, and highlight where modifications have been made to accommodate seasonally frozen soils. The poster will give a brief overview of the CRHM model and the study site, and provide a conceptualization of the field site and how it is represented in CRHM. Current modelling results will be shown comparing the simulated thaw depth and timing with observed values. In addition, evapotranspiration will be modelled using the penman Monteith combination approach and compared to observed actual evapotranspiration rates taken from an onsite eddy-covariance system.

Preferred Platform: Poster Presentation

Student Presenter: Y

CGU_H_02: Permafrost Hydrology

Conveners: Ryan Connon¹, Sean Carey², Élise Devoie³, Peter Morse⁴, William Quinton⁵ and Chris Spence⁶

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Controlling Factors on Lateral Permafrost Thaw in the Northwest Territories: A Numerical Study

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During the past decades, an increase in mean annual temperature has led to an acceleration in permafrost thaw rates in the northern hemisphere. Specifically, temperature increases are critical in Northwest Territories because the mean annual temperature is close to permafrost thaw temperature; thus, a slight increase in mean annual temperature in those areas can cause irreversible thaw. Simulations and field data indicate that discontinuous permafrost is thawing laterally in addition to the vertical thaw. Although vertical permafrost degradation has important effects on landscape evolution, lateral thaw and its controlling factors are of great importance and insufficiently studied. The formation of an open talik and advective heat transfer can be two factors laterally influencing permafrost. To study the controlling factors of lateral permafrost thaw, a realistic model is required. This research applies a recently developed multi-phase 2-D finite element model, with a non-isothermal phase change condition. The goal of this research is to quantify the internal and external driving forces in long-term lateral permafrost evolution via a thorough sensitivity analysis. The study domain of this research is based on a prototypical 2-D cross section of subsurface characteristics at the Scotty Creek research station in southern Northwest Territories, and the input energy profile of the top boundary is based on the field data collected from this site. The simulation results will illustrate the controlling factors in permafrost lateral thaw. Moreover, a sensitivity analysis demonstrates the relative dependency of thaw rates upon the rates of lateral advection, geothermal gradient, system heterogeneity, and snow/vegetation cover.

Preferred Platform: Oral Presentation

Student Presenter: Y

Modelling controls on local talik formation in discontinuous permafrost

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Taliks (perennially thawed soil in a permafrost environment) are generally associated with water bodies or wetlands, and their development and evolution is poorly documented. Isolated taliks (not associated with wetlands) have been observed at the Scotty Creek Research Station in the discontinuous permafrost region. These taliks have been expanding quickly both vertically and laterally over the past decade of monitoring. The main controls on this expansion are thought to be the incoming radiation, the advective heat flux, and the ability to transfer energy to the freezing/thawing front, determined by the soil thermal conductivity and the snowpack. These controls are investigated using field data to inform and validate a numerical model. Thaw rates and patterns observed in the field including accelerated thaw in regions between connected wetlands, moisture migration towards the freezing front, and enhanced refreeze depths at the borders of wetlands are modelled. The initial formation of a talik is highly dependent on the ground heat flux. Subsequent talik expansion is more susceptible to the impacts of advective flows, summer temperature and moisture conditions. Once formed, taliks tend to persist, with very few field measurements suggesting permafrost aggradation. Talik formation appears to follow a positive feedback loop wherein an isolated talik forms a local depression that collects water in the thawed season, increasing thermal conductivity and limiting tree root function. Decreased canopy health increases incoming radiation, allowing for talik expansion, increased subsidence, and additional ponding. Though most freeze-thaw models make the simplifying assumption of a saturated system, soil temperature data collected in the field indicate notable differences between saturated and unsaturated soil columns. The impact of these differences on talik formation is quantified to place limits on error resulting from neglecting variable saturation

Preferred Platform: Oral Presentation

Student Presenter: Y

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

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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 is 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 2015 in the Scotty Creek watershed, Northwest Territories. Water levels in bogs with varying levels of connection to the drainage network declined by 40 to 190 mm over this period. The water level in the channel fen did not significantly change over the 2003 to 2015 period of study, sustained by inputs from the increasingly connected network of bogs as permafrost barriers thawed. The water level in the monitored isolated bog did not significantly change over this period. Between the 1998 El-Niño year and 2012, runoff from Scotty Creek increased by 1000 mm beyond that expected from changing precipitation patterns alone. Approximately 100 mm of this increase can be attributed to moisture derived from thawing permafrost. Increasing connectivity between wetlands with the loss of permafrost and the associated expansion in contributing area accounts for the greatest proportion of the observed excess runoff (approximately 800 mm). Transient influences derived from permafrost thaw and wetland drainage represent smaller magnitude contributions to runoff as compared to long-term contributions from increasing wetland connectivity with thaw-induced land cover change.

Preferred Platform: Oral Presentation

Student Presenter: N

Modeling thermal transport during permafrost aggradation and thaw in peatlands

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Permafrost covers approximately 24% of the Northern Hemisphere. Its degradation is altering ecosystems and hydrology of the northern latitudes and is threatening stability of infrastructure founded on it. Thawing permafrost is also leading to increase in wetland area, consequently increasing hydrological connectivity between basins and affecting water and energy balance of the region. It is critical to understand the fundamental processes affecting permafrost thaw and transitional behaviour of the hydrological systems. To achieve this, a three-dimensional finite element numerical model is constructed for a region located in the Scotty Creek Research Basin in the Northwest Territories, Canada (61°18'N, 121°18'W). FEFLOW groundwater flow and heat transport modeling software is used in conjunction with the piFreeze plug-in, to account for phase changes between ice and water. A representative permafrost bulb is generated with both steady-state and transient approaches. The steady-state approach uses ground temperatures of -2.5 °C and 1.3 °C applied over the modern-day permafrost plateau and wetlands, respectively. Transient permafrost evolution to current conditions would require hundreds of years of climate variations over an evolving landscape. To develop a subsurface environment that matches field data collected since 1994, the model simulations are conducted in transient mode. The transient approach applies daily climatic data over the plateau between 1875 and 2015; the Simultaneous Heat and Water model (SHAW) is used to calculate ground temperatures and infiltration rates. Transient simulations with a daily time step are computationally demanding for the 2.4 million node model. Simulations advance at 2 to 3 years per 24 CPU hours on advanced workstations. Modelling permafrost aggradation / thaw will allow for the testing of remedial measures, such as mulching and borehole heat exchangers, to stabilize permafrost in high value infrastructure environments.

Preferred Platform: Oral Presentation

Student Presenter: Y

Self-leveling ice dam: a mechanism for bidirectional icing development

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Icings are widespread, poorly understood seasonal features in the northern hemisphere. Their formation has implications for groundwater discharge, water storage, spring freshet diversion, and winter geohazard development. Icing (also known as aufeis, naled, or overflow ice) development occurs in winter where successive overflows of groundwater freeze on the surface and create a sheet-like mass of ice. An icing grows in vertical extent as ice-layers accumulate, and in horizontal extent when new snow cover facilitates development of pipes and channels for water flow. Here we present multiple field observations of bidirectional water redistribution, with horizontal and vertical icing expansion, related to self-leveling ice dams that form in the local snow cover external to the icing. Ice dams with horizontal crests were observed at valley margins. Lateral diversion behind the dam allows groundwater redistribution from the source before overflow occurs. Counterintuitively, ice damming may also facilitate upslope redistribution of water on valley sides; apparent vertical migration of the dam was indicated at several sites by closure of overflow points below the crest, flow from points near or at the crest, and parallel horizontal lineations in the ice. During active overflow events we observed saturated snow behind the dam, level with the crest, and moist snow above the crest. We hypothesize that a portion of the moist snow freezes in contact with cold air, increasing the freeboard of the dam and thereby raising the hydrostatic potential. With subsequent water flow into the snowpack, this mechanism likely allows the dam crest to migrate upslope. These observations imply that water can migrate well beyond the spring outlet to grow the horizontal (and vertical) extent of the icing without the need for new snow. The observations have implications on remotely sensed estimations of icing volume that assume the maximum vertical extent and maximum thickness are related.

Preferred Platform: Oral Presentation

Student Presenter: N

A permafrost probability map for northwestern Canada's sporadic discontinuous permafrost zone

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Permafrost maps are required for northern development and infrastructure planning as well as climate change adaptation strategies. However, permafrost distribution throughout the Canadian subarctic is not particularly well understood due to a combination of the remoteness and size of the region, spatial and temporal heterogeneity, limited data availability, and incomplete monitoring networks. These factors highlight the challenges associated with establishing a comprehensive mapping effort of permafrost distribution, and given the impacts of climate change, further emphasize the need to improve techniques of remotely capturing and analyzing permafrost distribution. This study presents a map of permafrost probability across approximately 250,000km² of the sporadic discontinuous permafrost zone across the southern Northwest Territories, northeastern British Columbia and northern Alberta. The study region boundaries were defined by geographic constraints longitudinally – the Rocky Mountains to the west and Canadian Shield to the east. Latitudinally, the sporadic discontinuous permafrost zone is bounded by extensive discontinuous permafrost to the north and isolated patches to the south. This study quantifies permafrost probability using a trivariate air temperature model combined with peatland distribution, landcover, potential incoming solar radiation and soil type components. Average permafrost probability for the map was approximately 47% but varied greatly across the region with maximum probability nearing 90% in select areas of the Northwest Territories and minimum probability found to be approximately 7% near the southern map boundary. Augmenting our understanding of the unique conditions contributing to permafrost distribution, especially at a higher resolution than broadly available permafrost extent maps, is critical for studying any of the interdependent processes and systems in permafrost environments as well as predicting future interactions or responses.

Preferred Platform: Poster Presentation

Student Presenter: N

Effects of groundwater flow on permafrost distribution in a subarctic watershed

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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.

Preferred Platform: Poster Presentation

Student Presenter: Y

Identification of a dynamic temperature threshold for soil moisture freeze/thaw (F/T) state classification using the soil real dielectric constant.

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The use of microwave remote sensing for frozen ground detection has been well documented. Typical validation of these remotely sensed F/T state products relies on in-situ air or soil temperature measurements and a threshold of 0°C to identify frozen soil. However, in soil pores, the effects of capillary and adsorptive forces combine with the presence of dissolved salts to depress the freezing point. This is further confounded by the fact that water over this temperature range releases/absorbs latent heat of freezing/fusion. Indeed, recent results from SLAPEx2015, a campaign conducted to evaluate the ability to detect F/T state, suggest that using a 0°C soil temperature threshold for freezing may not be appropriate. Coaxial impedance sensors, like Steven's HydraProbeII (HP), are the most widely used soil sensor in water supply forecast and climatological networks. These soil moisture probes have recently been used to validate remote sensing F/T products. This kind of validation is still relatively uncommon and dependent on categorical techniques based on seasonal reference states of frozen and non-frozen soil conditions. An experiment was conducted to identify the correlation between the phase state of the soil moisture and the probe measurements. Eight soil cores were subjected to F/T transitions in an environmental chamber. For each core, at a depth of 2.5 cm, the temperature and real dielectric constant (rdc) were measured every five minutes using HPs while two heat pulse probes captured the apparent heat capacity 24 minutes apart. Preliminary results show the phase transition of water is bounded by inflection points in the soil temperature, attributed to latent heat. The rdc is highly sensitive to the phase change, opening up the possibility of estimating a dynamic temperature threshold for soil F/T classification. This technique provides a more accurate threshold for F/T product than the static reference temperature currently established.

Preferred Platform: Poster Presentation

Student Presenter: Y

Long-term runoff seasonality changes and its relationship with degrading frozen ground in the headwaters of the Yellow River

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Climate change impacts on runoff seasonality change are complexed, particularly in the headwaters of the Yellow River (HWYR) that is widely covered by climate-sensitive frozen ground. Previous research shows three major change periods of annual mean runoff (AR): pre-change period 1961-1989 (1960s, 1970s, 1980s), decrease period 1990-2002 (1990s), and recovery period 2003-2013 (2000s). Comparisons of the three daily mean runoff from the three periods shows that winter baseflow (WB), snowmelt runoff (SR) and wet-season runoff (WR) mainly occur in January-February, March-May and June-September, respectively. Moving T-test was employed to detect runoff change and climate change. Change points analysis showed that AR WR and AR WB have two change points, but SR has only one change point. Change points of WR are the same as AR which is mainly caused by precipitation and temperature changes. Change points analysis showed that AR WR and AR WB have two change points, but SR has only one change point. Change points of WR are the same as AR which is mainly caused by precipitation and temperature changes. Change points of WB and SR are different from WR and AR which are closely related to temperature change. SR reduction in 2000s were offset by increased winter baseflow.

Preferred Platform: Poster Presentation

Student Presenter: Y

What lies beneath: carbon dioxide exchange and evapotranspiration across intact and thawing permafrost landforms in subarctic Canada

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Warming temperatures across Canada's subarctic and arctic regions are causing permafrost landforms to thaw, resulting in rapid land cover change, including conversion of polygonal peat plateaus to wetland and thermokarst. These changes have important implications for the hydroecology of northern ecosystems, including shifting carbon uptake and release functions, which form feedbacks with climatic change. To determine the impact of changing land cover on the cycling of carbon dioxide (CO₂) and water vapour in a continuous permafrost region, four landscape units (peat plateau, sedge lawn, channel fen, and thermokarst) in the Hudson Bay Lowlands, northern Manitoba, were instrumented for regular (weekly) chamber measurements of CO₂ and vapour flux over a summer season (May to September 2014). Evapotranspiration (ET) peaked post-snowmelt, during rapid active layer thaw, and was lowest in peat plateaus relative to other landforms, likely due to soil moisture limitation. Peat plateaus acted as a consistent source of carbon to the atmosphere over the growing season (average net efflux of 5.5 g CO₂ m⁻² d⁻¹), driven by moderate respiration and low productivity. In contrast, both sedge lawn and fen channel landforms were consistently taking up CO₂ from the atmosphere driven by moderate respiration while being highly productive during peak growing season (gross ecological productivity values of -19.1 and -17.5 g CO₂ m⁻² d⁻¹ respectively). Thermokarst varied temporally between providing and taking up CO₂ to/from the atmosphere, driven by high respiration rates early in the season and sedge production throughout the later growing season. This work shows distinct rates of CO₂ exchange and ET between intact and thawing permafrost features. This has important implications for the hydroecological future of northern Canada, as well as for global feedbacks with climate change through scaling up the large land area of Canada which is underlain by rapidly thawing permafrost.

Preferred Platform: Oral Presentation

Student Presenter: Y

High frequency data provides new insights into stream biogeochemistry at an alpine headwater catchment underlain by discontinuous permafrost in Yukon

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Conceptual models of alpine watersheds underlain by permafrost have developed over the last 50 years based on careful field measurements and observations. More recently, the role of frozen soils in catchment biogeochemistry has received increased scrutiny due to warming temperatures and thawing permafrost. New water quality sensors (fluorometers, multi-parameter sondes) provide an opportunity to test and enhance our understanding of coupled water and biogeochemical cycling in headwater systems. In this work, multi-year multi-parameter high frequency data from Wolf Creek Research Basin, Yukon, Canada, were used to assess the influence of active layer development, permafrost and seasonality on runoff generation processes and catchment connectivity. High frequency (15 minute) specific conductivity (SpC) and coloured dissolved organic matter (CDOM) were used to generate seasonal and event-based hysteresis loops with discharge. SpC was inversely related to given flows (Q) throughout the season showing hysteresis at high frequency as the active layer thickened, leading to deeper flow pathways and enhanced water-soil contact. The general clockwise hysteresis for Q-SpC curves for storm events indicated lower salinity on the falling limb of the hydrograph and some dilution, however, it is more likely that this reflected water reporting from more dilute near-surface horizons later in the event. Q-CDOM showed a strong seasonal clockwise pattern with distinct counter-clockwise event patterns. As a proxy for dissolved organic matter, this represents a general flushing from spring to fall. However, on event time scales, CDOM loops indicated a rise after the peak discharge, which at event scales suggests a mobilization mechanism rather than flushing. Overall, high frequency data helped refine existing conceptual models of northern catchments by providing insights into biogeochemical dynamics at finer timescales that can be linked to other catchment characteristics.

Preferred Platform: Oral Presentation

Student Presenter: Y

CGU_H_03: Hydrological and biogeochemical behaviour in urban(izing) landscapes

Conveners: Claire Oswald¹ and Christopher Wellen²

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A tale of two city streams: Characterizing chemical and environmental drivers of organic contaminant dynamics in urban Canadian streams [Invited]

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Prominent characteristics of the urban landscape include impervious surface coverage and sewer networks that both serve to increase runoff delivery to streams and decrease infiltration. This can lead to rapid, often untreated inputs of contaminants to water bodies during snowmelt and rainfall. Of particular interest are how chemical and environmental properties interact during such events to influence contaminant delivery to streams. This study investigated the combined influence of chemical properties, urbanization, and hydrology on the transport of a broad range of organic contaminants in urban Canadian streams. In Toronto, Canada, we had three stream sampling sites in each of two watersheds that differ widely in their degree of urbanization, and hence the types and configurations of their land cover and city infrastructure. During two rainfall events and one snowmelt event, we measured a suite of organic contaminants including both classic (polycyclic aromatic hydrocarbons, herbicides) and emerging (benzotriazole ultraviolet stabilizers, benzotriazole corrosion inhibitors) organic contaminants covering a range of environmental partitioning and emissions characteristics. We also concurrently measured suspended sediment, dissolved and particulate organic carbon, stable water isotopes, and electrical conductivity. We combined this data to answer the following questions: 1) How do contaminant concentrations and yields compare between the two watersheds, and why? 2) Are the concentration patterns observed across snowmelt and rainfall events consistent, for all analytes, and why or why not?

Preferred Platform: Oral Presentation

Student Presenter: N

**THE DOWNSTREAM EFFECT OF A WASTEWATER TREATMENT PLANT
UPGRADE ON NITROUS OXIDE**

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Nutrient-rich effluents can drive biological processes in rivers and create major, well-characterized impacts on ecosystem health. Stimulation of processes such as nitrification and heterotrophic respiration can create stretches of hypoxic waters, leading to hot zones and hot periods of nitrous oxide (N₂O) production. In an effort to reduce downstream nitrogen loading, the Regina, Canada, Wastewater Treatment Plant (WWTP) recently underwent an upgrade to reduce the concentrations of total nitrogen and ammonium discharged into Wascana Creek. Wascana Creek is a highly impacted, effluent dominated system where streamflow can be up to 100% effluent. We assessed whether changing nitrogen loads could impact nitrogen processing and therefore lead to lower dissolved N₂O concentrations. A before-after-control-impact (BACI) design was used to quantify N₂O concentrations upstream and downstream of the effluent, before, during, and after the upgrade. Results showed that downstream (impact) sites exhibited significantly higher concentrations of N₂O than that of the upstream (control) site throughout the entirety of the monitoring period. Pre-upgrade N₂O concentrations immediately downstream of effluent discharge (~200 m) were, on average, 360 times greater than that of the upstream site. Further downstream, ~5 km and ~60 km, N₂O concentrations were 140 and 6 times higher, respectively, than the upstream control site. Post-upgrade, N₂O concentrations were not significantly different from the pre-upgrade period. The absence of change in N₂O concentrations at the impacted sites following the upgrade likely stems from saturation of the denitrification process. Overall, effluent-impacted reaches of Wascana Creek show strongly elevated concentrations of N₂O throughout the study, even after the WWTP upgrade.

Preferred Platform: Oral Presentation

Student Presenter: Y

Targeting ideal green stormwater infrastructure soils using unit soil water budgets

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To effectively reduce stormwater runoff in urban landscapes, green infrastructure (GI) must be optimized to create an artificial “hot-spot” and “hot moment” which occurs reliably for each rain event. Optimal GI soil amendments should: 1) infiltrate and evaporate at higher rates than surrounding developed landscapes, 2) maintain a minimum soil moisture content in between events without becoming hydrophobic, and 3) be locally available or easily blended. Soil water content affects GI hydrology and water quality performance because it is a limiting factor in evaporative fluxes and infiltration rates, as well as a controlling factor in both nitrogen and carbon emissions pathways. During events, damp soils have greater initial infiltration rates than saturated soils or very dry soils, which produce more runoff. After events, residual soil moisture dictates the upper limit available for losses to evaporation or plant transpiration. Soil particle size distributions have a large impact on soil water content: smaller particles create narrower pore spaces, which have stronger matric suction and remain wetter longer. Large particle sizes do not hold enough water in tension to allow plants in a GI structure. Therefore, soil media characteristics are major factors in the success or failure of individual GI systems, yet particle size distribution and chemistry are largely under-examined for GI design. There is limited information on the appropriate fill characteristics for these structures in various climates and applications. To address this need, estimated unit soil water budgets were calculated for all soils in the SWIG and NCSS Lab Data Mart soils databases. The unit soil water budgets were plotted on an adapted Water Budget Triangle tool to visualize and examine the physical and chemical characteristics of different natural soils in the context of their water budgets. Recommendations for maximizing gravitational and capillary water fractions in GI soils are presented.

Preferred Platform: Oral Presentation

Student Presenter: Y

A case of cautious optimism: INCA simulations suggest climate change drives future reductions in surface water chloride in New York State

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The application of road salts during winter months has led to a precipitous rise in concentrations of chloride (Cl-) measured in freshwater in the northeastern United States and Canada. Several studies have evaluated the potential impacts of altered snow management practices, generally concluding that reductions in future salt loadings may contribute to a delayed decline in the salinity of affected waters. However, prior approaches have not incorporated long-term changes in climate such as changes in winter snowfall rates. As climate change is projected to impact water resources during the 21st century, future changes to temperature and precipitation regimes should be incorporated into biogeochemical models in order to provide accurate and robust predictions of future biogeochemical changes. We use the Integrated Catchment (INCA) model to simulate future Cl- concentrations in two branches of the Tioughnioga River in central New York State, USA under dynamic climate and management practices (e.g. land cover and population change). We ran multiple simulations over three 30-year time periods (1961-1990; 2010-2039; 2040-2069; 2070-2099) to generate a range of plausible future outcomes. Model results suggest that Cl- concentrations may continue to rise steadily for several decades before beginning to decline approximately mid-century (around 2040-2069) as winter snowfall totals rapidly diminish and contributions from underlying aquifers sustain streamflow thereafter. Anthropogenic Cl sources (e.g. road salts) are reduced to account for shifting winter precipitation from snow to rain in far future scenarios (post 2040s) across four different future climate scenarios. Urbanized catchments that have undergone a greater degree of salinization may respond sluggishly compared to undeveloped regions, suggesting that both anthropogenic Cl sources and changing climate control future watershed responses.

Preferred Platform: Oral Presentation

Student Presenter: Y

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

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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, stormwater management, 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.

Preferred Platform: Oral Presentation

Student Presenter: Y

Flux of heavy metals along headwater streams during residential subdivision development

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While it is well known that urban streams are subject to impaired water quality, far less research has been directed at the acute modification of stream water quality during the urbanization process. This study determines the role of residential development construction activities on the transport of dissolved and particulate heavy metals along a headwater tributary of the Credit River in Brampton, Canada. Stream sites were sampled daily over a period of six months at locations representing varying stages of subdivision completion (upper site –active construction; middle site –finished construction and natural vegetation; lower site –finished construction and active construction). An adjacent stream draining an urban watershed served as a reference. Heavy metal loads in the urban stream were generally greater than the urbanizing stream, with the exception of a few winter storm events. Along the suburbanizing gradient, the upper stream site dominated by active construction had elevated levels of metals, particularly aluminum, copper, and zinc. The hydrological connection to a mid-reach zone of no-construction activity / fallow field and native forest resulted in lower metal flux. This suggests that the timing of construction activities and the hydrological connection between the stream and construction activities affect downstream export of metals.

Preferred Platform: Poster Presentation

Student Presenter: N

Seasonal Water Quality Dynamics in a Stormwater Management Pond

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Stormwater ponds (SWPs) are a ubiquitous feature in the urban landscape. SWPs were built to reduce flooding and riverbank erosion by retaining particulate-laden stormflow and are also believed to detain excessive pollutants in urban runoff. However, recent work has shown that fine scale pond processes may decrease their seston retention, and compromise downstream water quality. This study investigated the biogeochemical interactions of a SWP in Mississauga, Canada. The pond was sampled at least weekly and measured for in-situ temperature, dissolved oxygen (DO), pH, and specific conductivity (SPC). Surface water samples from the inflow, outflow and main bays were analyzed for total suspended solids (TSS), and total phosphorus (TP) in dissolved inorganic (SRP), organic (DOP), and particulate (PP) forms. Outflow TP was composed of 60% PP, 35% DOP and 5% SRP, and was 100µg/L greater than the inflow from October to January during baseflow periods. TP in all sections during this time ranged from 2-8X the Ontario Ministry of Environment and Energy's standard of 30 µg/L in lake water. Internal loading of P in the pond implies that outflows may influence downstream nutrient cycling. TSS had a 4X enrichment factor between inflow and outflow in October, whereas the pond retained TSS in November through January. Seasonal changes in the pond's sediment sink function suggests the occurrence of autumn resuspension and winter sediment capture. Variable particulate retention in the pond may risk local flooding by increased deposition in downstream waterways. Oxidic surface waters in the fall (10 mg/L) were contrasted by hypoxia (1 mg/L) during ice-over conditions. Low DO could alter sediment chemistry, and thus nutrient balances in the water column. The seasonal ability of the SWP to retain particulates and P shows it may contribute to eutrophication in local water bodies. Knowledge of these fluxes on finer temporal scales will allow for better management of current and future SWPs.

Preferred Platform: Poster Presentation

Student Presenter: Y

The influence of land use on dissolved organic carbon dynamics in a complex Great Lakes watershed

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Intensification of land use in the Great Lakes region has created complex landscapes composed of varying land cover, hydrological responses, and biogeochemical processes. As land use types are shifting between forest, wetland, agricultural, and residential, understanding how varying land use affects water quality in managed watersheds is becoming increasingly important. Complex watersheds with diverse land use types will have distinct aqueous carbon sources and concentrations of dissolved organic carbon (DOC). Understanding the quantity and quality of DOC is crucial as elevated DOC concentrations have negative implications on photosynthesis-dependent aquatic organisms and can enhance metal solubility. The objective of this research is to quantify and characterize DOC concentration and quality in a complex Great Lakes watershed with a diversity of land uses (Spencer Creek, ON). Streamflow regimes and other geochemical parameters were linked to DOC characterization through weekly measurements at 16-subcatchments during May - October 2016 and 2017. Fluorescence spectroscopy methods were used to fingerprint DOC signatures and relate these to land use types for each sub-catchment. Results indicate that DOC concentrations were highest in agricultural and wetland sites, and lowest in residential regions. DOC was characterized to be of terrestrial origin throughout the watershed with older and complex-structured DOC found in agricultural and wetland dominated areas. Overall, this research provides an assessment of how different land use types contribute to down-stream DOC concentrations and quality, and highlights the importance of land use within an urbanizing landscape on water quality.

Preferred Platform: Poster Presentation

Student Presenter: Y

The influence of channel complexity on trace metal geochemistry in salt impacted urban streams

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Widespread urbanization has led to increased trace metal and salt levels in urban streams because of significant local loadings. Geomorphic alterations prevalent in many urban areas, such as channel stabilization practices, alter flow, sediment and solute exchange processes between the stream channel and adjacent hyporheic zone. Hypothetically, these alterations may affect trace metal geochemistry in suspended solids, creating spatially discrete zones of varying trace metal dynamics. In this study we analyzed trace metal concentrations among sequentially extracted fractions in suspended sediments along discrete stretches of fluvial form (meandering and straight) and explored the influence of dissolved organic carbon, major cations and anions, and pH on trace metal distribution. In all, we sampled and surveyed 12 reaches of varying geomorphic and hydraulic characteristics in three urban watersheds. We analysed substrate texture, channel plan-form, bed slope, and degree of rehabilitation and structural controls. We then clustered these channel reaches into three distinct groups of complexity based on patterns observed in the particulate phases. Our results indicate that highly complex reaches (highly meandered with greater hyporheic connectivity) are associated with the highest concentrations of salt cations, and total recoverable and mobile fractions of metal elements. This study promotes a discourse on the role of stream geomorphology on trace metal phase distribution in salt impacted streams of highly urbanized watersheds.

Preferred Platform: Oral Presentation

Student Presenter: Y

CGU_H_04: Impacts of forest disturbances and climate change on watershed hydrology and biogeochemistry

Conveners: Qiang Li¹, M. Altaf Arain², Michael Pisaric³, Fan-Rui Meng⁴, Adam Xiaohua Wei⁵

Co-chairs: Qiang Li¹, M. Altaf Arain², Michael Pisaric³, Fan-Rui Meng⁴

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Influence of a low severity wildfire on runoff flow path and pore water chemistry of a peat plateau, Scotty Creek, NWT

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One manifestation of a warming climate is the increase in fire frequency, size and severity of naturally ignited wildfires throughout northwestern Canada. In the zone of discontinuous permafrost, the snowpack provides a significant source of freshwater that is released over a short time period during spring snowmelt through the shallow, thawed active layer. Combustion of surface vegetation and soil organic matter can alter canopy coverage, surface albedo, evapotranspiration, and the physical structure and pore water chemical composition of peat soils, and can have severe implications for permafrost stability. In June 2014, a low severity wildfire that burned approximately one-half of a peat plateau in the Scotty Creek drainage basin in the Northwest Territories, Canada provides a unique opportunity to examine the effects of a low severity, localized wildfire a single landform unit. Pore water samples collected throughout the thaw season show elevated solute concentrations in the burn. Laboratory analysis of ten 20-cm peat cores show increased bulk density in the burn accompanied by a reduction of pore size and porosity, and increased water retention with depth. Ash, particulates, and leachate from dead organic matter that translocated through the profile resulted in clogging of open pore spaces. Higher moisture content promotes leaching and dissolution, and deeper ground thaw that also contributes solute. This study suggests that low severity wildfires that lightly scorch the peat surface, but result in little or no organic matter loss, can have a significant impact on the health and stability of the local ecosystem.

Preferred Platform: Oral Presentation

Student Presenter: Y

Evaluating the effects of climatic variability and phenology on carbon and energy cycles in a managed temperate deciduous forest in southern Ontario

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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. Recent studies indicate major challenges for forests ecosystems due to extreme weather events and human activity, comprising the abilities of these different-age forests to sequester atmospheric CO₂ and impacting the regional climate and hydrologic cycles. The objectives of this research were to quantify fluxes in a unique ecozone, and determine the impact of phenology. Recent studies suggest special consideration is needed for deciduous forests, such as temperate hardwood forests as seasonal carbon cycles are influenced by leaf emergence and senescence. This research investigated carbon and energy fluxes using the eddy covariance method for a five year period (2012-2016) of data at a 90-year old managed deciduous located at the northern edge of the temperate deciduous biome in North America. The highest annual net ecosystem productivity (NEP) was measured in 2014 (305 g C m⁻²), a wet year 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, decreased summer PAR, and low annual temperature. Through the analysis of eddy covariance and meteorological measurements, this research looked to understand patterns of carbon exchange in temperate deciduous forests and how they responded to climatic inter-annual variability and phenological changes.

Preferred Platform: Oral Presentation

Student Presenter: Y

Effects of forestry on late summer low flows and fish habitat in three snow-dominated catchments of the Pacific Northwest

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Reductions in forest cover associated with harvesting and natural disturbance often result in an advanced snowmelt freshet and earlier peak flow. Most studies have focused on changes in annual water yield and peak flow, and have not focused on late-summer low flows, which are often critical for resident fish because of the corresponding reduction in habitat. This study considered the impacts of forestry on low flows and fish habitat in three catchments, two about 5 km² in area and one 30 km², located in the southern interior of B.C. A paired-catchment analysis was applied for each day-of-year, with the post-harvest period divided into three sub-periods of about seven years. Instream flow habitat surveys were combined with application of the physical habitat simulation (PHABSIM) model to develop a relation between streamflow and weighted usable area, a metric of hydraulic habitat, for rainbow trout parr and fry. In two of the three catchments, late-summer streamflow was consistently less than the predictions from the pre-harvest regression, beginning about 15 to 20 years after harvest. This result suggests that the regenerating forest stand produces greater transpiration loss than the original mature forest. The habitat modelling indicates a reduction of up to 40% of available habitat for the resident rainbow trout for the two catchments. These results begin to fill an important gap in our knowledge about longer-term impacts of logging on summer low-flows and fish habitat in small snowmelt dominated hydrological systems of the Pacific Northwest.

Preferred Platform: Oral Presentation

Student Presenter: Y

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

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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. 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. 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 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.

Preferred Platform: Oral Presentation

Student Presenter: Y

Empirical stream thermal sensitivities may underestimate stream temperature response to climate warming

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There are conflicting predictions on how headwater streams in western North America will respond to climate change. Those using statistical relationships between stream and air temperatures, commonly referred to as empirical stream thermal sensitivity, suggest that existing cold water streams in snow influenced catchments will be the most resilient to increased air temperatures; whereas, studies employing coupled stream temperature and hydrologic models suggest that streams in these regions will be highly responsive to increased air temperature. In this study we attempt to reconcile some of these discrepancies in stream temperature predictions for headwater catchments influenced by snow. We use a process-based hydrology and stream temperature model to generate 50 year records of discharge and stream temperature for headwater catchments with varying elevations and snow regimes. We then use the model to simulate climate warming scenarios and compare the modelled stream temperature response to those estimated using the stream thermal sensitivity approach. We show that stream thermal sensitivities may underestimate stream temperature response to climate warming, in some cases by as much as a factor of four. In addition, we illustrate that thermal sensitivity estimates are heavily influenced by the number of years used in their estimation. We conclude that stream thermal sensitivities may provide a misleading portrayal of how streams might respond to future climate warming and that more process-based understanding of stream thermal regimes is needed to effectively manage these catchments.

Preferred Platform: Oral Presentation

Student Presenter: N

Climate and Stand Density Effects on Growth in a Red Pine Plantation in Southern Ontario

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Forest management activities such as variable retention harvesting (VRH) have a profound influence on stand structure that may impact forest growth and resilience to climate stresses. In this study, VRH treatment was applied to an 83-year-old (in 2016) red pine (*Pinus resinosa*) plantation in southern Ontario, Canada. The study site is unique in that it was planted to afforest degraded agricultural lands using a tree species that was likely not present on the site prior to settlement. The plantation is located near the southern margin of its native range and the species is likely vulnerable to a warmer climate. In 2014, the plantation was subdivided and thinned using aggregate and dispersed harvesting treatment at two densities (55% and 33% crown retention) while some areas were untreated. The response of forest growth to climate factors and VRH treatment was characterized through tree-ring chronologies constructed from 106 tree cores collected throughout the plantation. The standardized chronologies were compared to long-term climate data. The climate influences on growth prior to VRH treatment were found to be inversely-related ($p < 0.01$) to growing season air temperature over the past 80 years (AD 1935 to 2013). Drought indices (e.g. PDSI) ($p < 0.01$) and potential evaporation ($p < 0.05$) were also significant controls during the summer months over this period. Following VRH treatment, radial growth in residual trees in aggregate and dispersed plots (both 33% and 55% canopy retention) demonstrated enhanced growth compared to the control plots which may be an early indicator of how growth is responding to the treatment. The value of this research was the examination of climate factors driving radial growth in this plantation. This in turn will provide valuable background information to rigorously examine post thinning responses of the individual treatments in the next stage of research under the Global Water Futures (GWF) network.

Preferred Platform: Oral Presentation

Student Presenter: Y

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

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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.

Preferred Platform: Oral Presentation

Student Presenter: Y

Form and bioavailability of phosphorus in fine sediment stored in a gravel bed river

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Landscape disturbance pressures in forested headwater regions alter the supply and delivery of sediment and associated nutrients to river networks. Particulate phosphorus forms bound to fine sediment can infiltrate gravel bed deposits and may represent a potential legacy of nutrient loading in riverine ecosystems. In this study, six study sites were selected to reflect increasing downstream sediment pressures from a range of landscape disturbance pressures (harvesting, wildfire, urbanization, sewage effluent) in the Crowsnest River Alberta during low flow. A sequential extraction scheme was used to fractionate particulate P into non-apatite P (NAIP), apatite P (AP) and organic P (OP). The major element composition and particulate P forms of both river bed and suspended sediment were determined to evaluate inter and intra site differences in particulate P form. As well as to assess the abiotic controls governing particulate P forms in response to increasing land disturbance pressure. The results show a downstream increase in the percentage of bioavailable particulate P (NAIP) with increasing disturbance pressure. NAIP was strongly associated with increasing concentrations of metal oxides and organic carbon in the sediment. Landscape disturbances exhibited differences in particulate P forms but these differences were more pronounced in suspended than riverbed sediment most likely because of different biogeochemical processes in the water column and the hyporheic zone during low flow. In forested headwater regions, fine sediment in gravel-bed rivers may represent an important long-term source of in-stream bioavailable P that contributes to a legacy of disturbance pressures on the water quality and aquatic ecology of downstream environments such as reservoirs.

Preferred Platform: Oral Presentation

Student Presenter: Caitlin Watt

**The sensitivity of forest carbon fluxes to heat and drought climate extreme events –
seasonal pattern across forests in North American**

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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 temperature and soil water content anomalies, using relatively normalized daily data from 31 sites (324 site/year) in North American in the FLUXNET2015 dataset. The seasonal pattern of NEP, GPP and RE response to heat and drought anomalies were compared among different forest types, stand ages, management strategies, and climate condition. The results shew seasonal variations have a strong impact on forests sensitivity to heat and drought stress. The sensitivity of GPP and RE to temperature anomalies increase with mean annual temperature (MAT) in summer but decrease with MAT in spring. Heatwaves in spring have a positive impact on NEP in evergreen forests but a negative impact in most of the deciduous forests. The drought-induced decrease of NEP in spring and autumn were driven by the reduction of GEP in most of the sites, while the sensitivity of GEP and RE to summer drought were not significantly different. 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.

Preferred Platform: Oral Presentation

Student Presenter: N

**Hydrologic function of a moderate-rich fen watershed in the Athabasca Oil Sands Region
of the Western Boreal Plain, northern Alberta**

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Peatlands are a dominant land feature in the Athabasca Oil Sands Region (AOSR) of the Western Boreal Plain (WBP), comprising 50% of the total land area, the majority of which are moderate-rich fens. Few studies have explored the hydrogeologic setting of moderate-rich fens in the WBP, yet their carbon stocks are susceptible to degradation through anthropogenic- and climate-related factors. This study provides the first hydrogeologic assessment of a moderate-rich fen in the AOSR; it is located in a meltwater channel belt characterized by relatively thin outwash sand and gravel (~7 m) underlying the peat. Lithological, geochemical, and hydrological results all point to the dominance of a local flow system supplying groundwater to the fen areas, evidenced by a thick (~16 m) and shallow (~7 m below ground surface) aquitard underlying the outwash, restricting hydrological connectivity between the fen and underlying regional aquifers. Vertical hydraulic gradients between peat and underlying mineral layers, as well as horizontal hydraulic gradients between fen and upland, were variable between 2011-2015, when groundwater discharge to the fen was enhanced during wet periods characterized by high rainfall. Conversely, flow reversals (groundwater recharge; fen to underlying mineral and upland) and subsequent water table drawdown persisted during extended dry periods. These flow reversals, in response to diurnal precipitation trends, confirm the dominance of a local flow-system, with hydraulic head in the underlying shallow mineral layer highly susceptible to fluctuations in the presence and absence of precipitation-driven recharge from adjacent uplands. Moderate-rich fens similar to that studied here ('Poplar Fen') will likely become more susceptible to drying in the future, leading to enhanced water table drawdown, peat oxidation and subsequent decomposition, and seral succession to a more ombrogenous peatland system, and be more vulnerable to wildfire.

Preferred Platform: Poster Presentation

Student Presenter: Y

Stream chemistry response to cumulative effects of forest harvesting, recovery from acidic deposition and a changing climate in a deciduous forest lan

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Studies investigating the impacts of forest harvesting on stream chemistry have been of short duration and interpreted only within the context of the harvest and not other environmental pressures acting on the forest ecosystem. Changes in atmospheric deposition and climate may confound how additional disturbances such as forest harvesting impact stream chemistry and its recovery. The study was conducted within catchments of the Turkey Lakes Watershed experimental watershed in northeastern Ontario, Canada. In the late summer and fall of 1997 three catchments within the watershed were harvested using differing silvicultural systems (diameter-limit, shelterwood and selection cutting) followed by natural stand regeneration. A before-after control-impact paired-catchment approach was used to evaluate whether harvesting resulted in changes to catchment stream chemistry concentrations and loads. Stream chemistry from the control catchments were reflective of long-term changes in acidic deposition and climate change that influenced internal nutrient cycling. Overlaying the gradual changes in stream chemistry were variable harvesting-related impacts on stream chemistry that were characterized by: 1) immediate impact followed by rapid recovery (e.g. cations); 2) immediate impact followed by slow recovery (e.g., K, DOC); 3) immediate impact then reversal in response (e.g. Cl, NO₃⁻); or 4) immediate and sustained impact (e.g. SiO₂). Some of the harvesting-induced changes in stream chemistry exacerbated changes due to acidification recovery and climate change while others counteracted their effect. These results emphasize the need for long-term monitoring to properly interpret the consequences of forest management activities in the presence of global change.

Preferred Platform: Poster Presentation

Student Presenter: N

The Effects of Black Spruce Fuel Management on Surface Fuel Condition and Peat Burn Severity in an Experimental Prescribed Fire

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The areal extent, frequency and severity of wildfires across Canada's Boreal region are predicted to increase under future climate, while residential and industrial land-use area continues to expand. Consequently, the area of wildland-urban interface (WUI) in need of protection from the intensifying wildfire regime is increasing. Wildfire management aims to protect people, property and infrastructure, and a key tool to achieve this is fuel management. Fuel management techniques were traditionally developed for upland, deciduous forest stands but in the Boreal Plains, the WUI landscape is made up of both deciduous uplands, and coniferous (mainly black spruce, *Picea mariana*) lowlands. Black spruce stands are often underlain by thick peat deposits and recent research has shown the potential for these systems to experience high severity burns. The ignition of high density, low moisture content peat can lead to smouldering combustion and large carbon emissions, presenting a challenge for wildfire management. Traditional fuel management such as mulching treatments (converting surface and canopy fuel to a masticated fuel bed) have been applied to black spruce stands, yet the impact on fuel load, fuel condition and carbon emissions is unclear. Our research compares the effects of two mulching treatments applied to a black spruce peatland that was subject to an experimental prescribed fire. We found that fuel treatment significantly increased near-surface peat bulk density, while a greater covering of mulch was correlated with increased the peat moisture content, overall leading to reduced peat burn severity in fuel-treated areas. However, total carbon loss was strongly correlated with mulch depth due to the presence of large amounts of fine fuels. Our findings suggest that wildfire in recently treated black spruce stands present an improved fire management risk due to reduced smouldering, while having a negative impact on wildfire carbon emissions.

Preferred Platform: Poster Presentation

Student Presenter: Y

CGU_H_06: Field Monitoring and Numerical Modelling in River Ice Engineering

Conveners: Shawn Clark¹

Co-chairs: Shawn Clark, Karen Dow, Benoit Turcotte

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Longitudinal, transverse, and temporal measurements of supercooling events in a 13 kilometer reach of the Peace River

Joel Evans

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BC Hydro owns and operates the W.A.C. Bennett and Peace Canyon dams on the Peace River in northern British Columbia. BC Hydro along with Alberta Environment and Parks monitors the formation and break-up of the ice cover as it relates to the potential for ice jam flooding at the Town of Peace River, Alberta. To improve river ice forecasting models to manage this risk a water temperature study is being conducted. During the 2016/17 winter, we deployed five high accuracy temperature data loggers on the bed of the Peace River upstream and downstream of the Dunvegan bridge in Alberta. During the 2017/18 winter we deployed nine of the same loggers in some of the same and similar locations throughout a 13 kilometer stretch of the river. In two locations each year the data loggers were deployed at the same river kilometer, on the left and right banks, to document the transverse variations in temperature during super cooling events. Water temperatures along this stretch of the river were also recorded during separate trips during both winters along the river thalweg at a depth of 0.5 meters. The longitudinal, transverse, and temporal extents of supercooling events will be presented.

Preferred Platform: Oral Presentation

Student Presenter: N

What causes river ice covers to consolidate? Insights from the 2017 – 2018 freeze-up on the Peace River, AB

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BC Hydro owns and operates the W.A.C. Bennett and Peace Canyon dams on the Peace River in northern British Columbia. BC Hydro along with Alberta Environment and Parks monitors the formation and break-up of the river ice cover downstream of the dams as it relates to the potential for ice jam flooding at locations including the Town of Peace River, Alberta. Despite operational procedures in place during ice cover formation to limit the impact of consolidations; environmental factors can cause consolidations of the ice cover leading to high water levels at freeze-up. A large consolidation of the ice cover took place during this past winter, entirely downstream of the Town of Peace River, triggered by warm weather following a period of cold weather. This presentation describes that event, looks at the environmental factors that likely caused it, and considers the role that anchor ice release waves played. Later in the winter another sequence of cold and warm weather, which did not trigger a large consolidation, will also be examined and compared to gain insight into factors that cause these events which are difficult to predict.

Preferred Platform: Oral Presentation

Student Presenter: No

Monitoring, Modeling, and an Image Processing Algorithm to Quantify River Ice Formation Processes on the Red and Assiniboine River

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To date, only empirical methods have been developed for the estimation of river ice formation processes. However, the option to use physical methods would further expand the tools available for water resources professionals to more effectively manipulate ice-affected river hydraulics. These methods can be developed through the study of a greater quantity and quality of data on the physical mechanisms that drive river ice formation. Unfortunately, collecting river ice data in the field can be dangerous and the available tools to do so are limited. Ice formation processes have been monitored on the Red and Assiniboine River in Manitoba by establishing an extensive network of hydrometric equipment and trail cameras. Although much of the study area is often subject to mechanical freeze-up jams, thermally driven border ice growth is typically observed just upstream of the Assiniboine's confluence with the Red River. Using photogrammetry and a digital image processing algorithm, border ice growth rates can be quantified using time-lapse photography. The developed techniques provide high frequency data that is a safe and economic alternative to intervalled site surveys. To demonstrate a practical application for the introduced methods of data acquisition, a CRISSP2D model has been calibrated using the collected hydrometric and border ice growth data.

Preferred Platform: Oral Presentation

Student Presenter: Y

**Field Monitoring of Freeze-up Consolidation Events on the Lower Dauphin River,
Manitoba, Canada**

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Fast moving rivers develop an ice cover through a series of dynamic consolidation events that can cause over-thickening of the ice cover and rapid changes in water level. The freeze-up regime of the Dauphin River in central Manitoba has been monitored since 2014 as part of the NSERC/Manitoba Hydro Industrial Research Chair in River Ice Engineering. Consolidation events on this river have historically resulted in thick ice accumulations that constrict the flow and raise water levels 4-5 m or higher above open water conditions. The freeze-up of 2017-2018 was particularly severe, as the consolidated ice cover caused flooding of Provincial Road 513 and the emergency evacuation of a community situated along the river. The 2017-2018 monitoring program was the most extensive to date, including the deployment of 21 Solinst Leveloggers, 10 HOBO Water Level Loggers, and 12 trail cameras on the 11.2 km reach of the Lower Dauphin River. This equipment captured high-frequency data related to ice consolidation events during freeze-up. Top-of-ice elevations were surveyed to obtain a peak ice elevation profile along the river and estimates of final ice thickness at several sites; at one site the consolidated ice cover reached approximately 8-10 m above the bed elevation. An unmanned aerial vehicle was used to conduct photogrammetric surveys at selected sites during and after freeze-up. This method was found to work well, providing a safe way to obtain a digital elevation model of a portion of the ice cover that is not accessible by using traditional RTK survey equipment. The 2017-2018 data was compared with previous years' datasets to draw conclusions regarding the effects of hydraulic and meteorological conditions on the severity of consolidation events and potential for flooding; the data suggests that mild air temperatures during freeze-up tend to cause severe ice conditions, and that discharge (over the observed range) may play a less important role.

Preferred Platform: Oral Presentation

Student Presenter: Y

Kashechewan First Nation Ice Jam Flood Risk Modeling

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The Kashechewan First Nation (KFN) community is located on a floodplain of the north branch of the Albany River, on the west coast of James Bay. Each spring the community faces the uncertain prospect of evacuation to limit damages from ice-jam flooding, which have occurred on a precautionary basis on 10 occasions since 1976, the most severe of which occurred in the spring of 2006. Hatch, Ltd. and Clarkson University conducted a study to develop long-term options for reducing the flood risk to the community. This summary presents the work to develop and analyze flood mitigation options using a two-dimensional river ice dynamics model, DynaRICE. Model parameters were calibrated using sparse data collected during the 2006 ice jam event. The model was used to estimate the critical ice-jam flood design event and determine the effectiveness of the mitigation options under this design event. Mitigation options included dams, dykes, pier and weir type ice control structures, and conveyance channels. To determine the critical ice-jam design event, substantially higher flows were examined with the model. Flows with return periods up to 1 in 10,000 years, plus the probable maximum flood, were examined. While the impact of the critical ice-jam flood event depends on the flow magnitude, there exists an incipient flushing flow which, when exceeded, will result in lower water levels at the community. For the Lower Albany River and the community, this incipient flushing flow was found to be equivalent to a 1 in 5000-year flow. That is, the most critical flood event to the community was found to be the 1 in 5000-year flow coupled with an ice jam at the community and was used as the design flow for the ice flood mitigation measures examined for the KFN. Flows associated with both lower and higher return periods result in lower flood levels. In the former, the lower levels result from lower volumes of water. In the latter, the higher flows serve to flush away the ice jam.

Preferred Platform: Oral Presentation

Student Presenter: N

Numerical Modelling of Ice Conditions Near Jenpeg Generating Station

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Jenpeg is the most upstream generating station on the Nelson River, and also functions to regulate outflows from Lake Winnipeg. A complex hydraulic network upstream of the station comprises natural and constructed channels. Outflows from Jenpeg are reduced during freeze-up to promote stable ice cover formation. Operating decisions made during the Ice Stabilization Program are informed by observation of water levels, water temperatures, weather forecasts and ice conditions upstream of Jenpeg and downstream on Cross Lake. Decision support systems, including numerical models, can serve to help optimize the timing and magnitude of flow cutbacks. This can improve ice conditions for other waterway users and enhance hydroelectric generation at Jenpeg and downstream generating stations on the Nelson River. The purpose of this study is to further develop a CRISSP2D numerical model to simulate the effects of the Ice Stabilization Program on the freeze-up ice regime. In this study, bathymetric surveys were completed to complement historical data and improve representation of the channel bed at critical locations. A network of trail cameras and temperature sensors was installed to monitor ice processes. Historical helicopter photos and satellite images (e.g., RADARSAT-2) were compiled for the freeze-up period. The CRISSP2D model was tested for multiple calibration years, and was applied in a real-time operational setting during the 2017 Ice Stabilization Program. The numerical model accurately simulates flow split hydrodynamics through the study area as well as the large scale ice processes present in this reach of the river. Effects of flow cutbacks on hydraulic controls in rapid sections are observed through simulations. The suite of field data collected furthers understanding of freeze-up mechanisms at this site, including border ice growth and ice front progression. Areas for future work in the continued development of the model will also be presented.

Preferred Platform: Oral Presentation

Student Presenter: Y

Leading Edge Effects on Turbulent Flow Field beneath an Ice Block

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Flow separation at the leading edge of ice blocks causes a low-pressure region beneath the block. The reduction in pressure beneath the block can contribute to its instability by either submerging or under-turning it. When the flow separates, there is also the generation of vortices at the leading edge of the ice block. These vortices have a tendency of propagating downstream. Propagation of the vortices, which are largely controlled by the leading-edge geometry, may result in instability of the ice block as well. The fluctuating pressure field is greatly dependent on the velocity field; therefore, it is important to conduct detailed velocity measurements to examine the flow dynamics beneath the ice block. The purpose of the present investigation is to explore effect of leading edge geometry of the ice block on the flow dynamics. To achieve this objective, four different leading-edge geometries (rectangular, round, upward and downward triangular shapes) were machined from a one-inch acrylic sheet. The ice block thickness to water depth ratio was maintained at 0.15 for the different leading-edge geometries. A high resolution planar particle image velocimetry system was used to conduct detailed velocity measurements at the leading-edge and beneath the block. Initial analysis of the mean flow revealed the creation of a recirculation eddy close to the leading edge of the rectangular and upward triangular ice blocks. A reattachment length of $0.57h$ and $0.40h$ (where h is the water depth) was attained for the rectangular and upward triangular configurations, respectively. There was however, no recirculation eddy created beneath the ice block for the round and downward triangular configurations. The final paper will include detailed discussion of the turbulent field, specifically, examining one-point statistics of the turbulence intensities and the topography of the Reynolds shear stress distribution beneath the block.

Preferred Platform: Oral Presentation

Student Presenter: N

Assessing the ice-induced and open water flood risk at St. Raymond, QC

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The St. Anne River flows through St. Raymond, QC. Over the years, the downtown area has been regularly affected by open water floods, frazil-induced floods and ice jam-induced floods. The Quebec Government has funded a pilot project to monitor the river as well as to determine the flood frequency and the vulnerability in order to implement efficient and sustainable flood mitigation measures. Based on three winters of intense monitoring and observation, and using ice processes simulation models as well as empirical relationship developed at Laval University, QC, the flood risk has been estimated, 70% of which is related to ice. This presentation describes the different steps of the methodology and discusses the results in a climate change perspective. This study is of great significance for a cold country like Canada where ice-induced floods are largely overlooked while massive resources are currently being deployed to delineate flood zones.

Preferred Platform: Oral Presentation

Student Presenter: No

Physical study of the consolidation resistance of a rubble river ice cover exposed to freezing ambient conditions

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River ice behaviour during freeze-up depends on a complex interdependent relationship between dynamic and thermal processes. An apparatus was constructed in a refrigerated room at the University of Manitoba to experimentally investigate the effects of cold ambient air temperatures on the ability of a rubble ice cover to resist consolidation (mechanical thickening) under externally applied forces. The apparatus consists of a translating plate that was used to deform a floating rubble ice cover in a waterproof tank. Rubble ice covers of varying thicknesses were exposed to an ambient air temperature of -10.5°C for specified durations of time. During this time, the interstitial water between the rubble pieces at the surface froze, creating a solid crust that solidified a portion of the surface rubble together. During the strength testing phase, the plate applied a uniaxial force to the ice cover and instruments were used to measure the displacement of the plate and resisting force generated by the ice cover. Results indicate that even short durations of freezing have a considerable impact on the peak strength of an ice cover; the consolidation resistance of a rubble ice cover after two hours of exposure to air at -10.5°C was over 30 times that of an equivalent unfrozen accumulation of rubble ice. The computed failure stress of the solid crust was found to increase with freezing index, and was approximately 1.5 MPa after 1300 degree-minutes-of-freezing. Consolidation resistance did not show a strong dependence on rubble layer thickness. Results from this study can be used to enhance the ability of numerical river ice models to more accurately simulate freeze-up ice dynamics, leading to more precise estimates of ice thickness and the associated effects on water levels.

Preferred Platform: Poster Presentation

Student Presenter: Y

CGU_H_08: Coupled Hydrological and Biogeochemical Functions, Part I: Wetland Ecosystems

Conveners: Colin McCarter^{1,3}, Fereidoun Rezanezhad¹, Maria Strack², Jonathan Price², Carl Mitchell³

Co-chairs: Colin McCarter^{1,3}, Fereidoun Rezanezhad¹, Maria Strack², Jonathan Price², Carl Mitchell³

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The initial biometeorological development of a constructed watershed

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Resource extraction industries operating in the boreal region of Canada have recently attempted construction of integrated boreal plains watersheds. This study presents the first few years of surface-atmosphere carbon (C) exchange from the Sandhill Fen Watershed (SFW). The SFW is a mix of engineered sandy upland regions, organic rich mineral soil midland and lowland regions. The watershed is designed as integrated boreal plains ecosystem which would encourage saturated soils and peat development in the lowland region. An analysis of soil ion fluxes, as recorded by exchange resins, indicate highly reduced conditions developing in the soils of the lowland region. The reduced conditions resulted in suppressed soil respiration (R) which was monitored both during the daytime with opaque static chambers and at nighttime via the eddy covariance technique. Despite the reduced conditions the methane fluxes also remained low over the monitoring period, likely as a result of high sulphate availability. By the end of the third year, the lowland was already sequestering $77 \text{ g CO}_2 \text{ m}^{-2} \text{ yr}^{-1}$, while the midland and upland remained sources of CO_2 . The difference in sequestration rates between the ecosystems is due to the reduced soil R and not differences in productivity as the lowland and upland have similar rates of gross primary production (GPP). The midland had the greatest rates of GPP, but also the greatest rates of R. With no other significant outflows of C the SFW lowland has started to accumulate organic matter. This initial landscape 'success' of creating a organic matter accumulating system is due to the soil pore scale processes which limit replenishment of alternative electron acceptors and foster highly reduced conditions in the soils.

Preferred Platform: Oral Presentation

Student Presenter: Y

Changes to the hydrophysical properties of upland soils in the Athabasca Oil Sands Region following wildfire

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In the Athabasca Oil Sands Region (AOSR), northern Alberta, moderate-rich fens are the dominant peatland type, interacting with adjacent forested uplands. Wildfire alters the hydrophysical and chemical properties of upland soils, including water retention, wettability, infiltration and surface runoff, ultimately altering the water balance. The effects of fire on soil varies with the physical properties, moisture conditions and vegetation cover of a soil, and the thermal characteristics of a fire. We explore changes to the hydrophysical and chemical properties of upland soils in a moderate-rich fen watershed in the AOSR following wildfire, to better understand how these changes alter the hydrologic role of uplands, and their implications for wetland function. Two different burned and unburned upland types were studied: a coarse-grained jack pine-dominated brunisol upland; and a finer-grained black spruce riparian upland. Results illustrated significant increases in infiltration rates in WDPT and % ethanol in the upper organic layer of burned cores suggests that wildfire reduced hydrophobicity at the surface, due to the decimation of the moss layer, which under low moisture contents exhibit hydrophobicity. Lastly, little difference was found between the moisture retention of burned and unburned brunisol soils, which both exhibited a relatively low retention capacity. Larger differences were found between burned and unburned riparian uplands, where burned cores exhibited much lower retention capacity. We conclude that these physical and chemical changes to upland soils following wildfire may lead to a net gain in groundwater recharge, which will help maintain the hydrological connections necessary for generating the local groundwater flow systems that feed adjacent fen areas. This feedback will help sustain high fen water levels necessary for moss recovery.

Preferred Platform: Oral Presentation

Student Presenter: Y

Water and energy fluxes at a disturbed and rewetted white beakrush-sphagnum site in a raised bog near Vancouver, British Columbia.

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Energy and water fluxes were studied in the center of the Burns Bog Ecological Conservancy Area (BBECA), a 20 km² raised maritime bog about 15 km south-east of Vancouver. A flux tower was installed at a disturbed white beakrush-sphagnum dominated site, with a negligible topographic gradient. Since summer 2014, an eddy-covariance system measures sensible and latent heat fluxes and climate sensors record precipitation, radiation, temperature, relative humidity and wind. Soil temperature was measured at three depths. Five nests, each comprising three piezometers and one well, were arranged in a cross, centred on the flux tower. Vertical water flux was computed from piezometer measurements, while water table elevation was used to compute horizontal gradients. Soil heat flux was calculated from numerically integrated soil temperature profiles and energy balance closure was achieved by means of the Bowen-ratio approach. The energy balance was quantified for the years 2014 to spring 2018, while the water balance was calculated between summer 2016 and spring 2018. Dominance of latent heat flux varied between years, and monthly averages were always directed away from the surface, while sensible heat and ground heat flux showed seasonal change in orientation, directed towards the surface in winter. Water storage change was computed as the sum of change in specific yield and specific storage. During summer, when the water table was below the surface and weak hydraulic gradients limited subsurface flow divergence, precipitation minus corrected evapotranspiration agreed well with computed storage change. During winter, when the water table rose above the surface, precipitation minus evapotranspiration significantly exceeded storage change computed from water level measurements, with the surplus assumed to leave the site as overland flow.

Preferred Platform: Oral Presentation

Student Presenter: Y

Overcoming the capillary barrier effect in cut-over peatland restoration: the impact of mechanical compression on CO₂ exchange

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Despite active restoration, cut-over peatlands remain persistent carbon sources for approximately 10 years, even though ~ 20 cm of Sphagnum moss has grown. This has been linked to the formation of a capillary barrier between the remnant cutover peat and the regenerated Sphagnum moss which lowers soil water content at the surface, and decreases productivity in comparison to natural analogues. Results from a field study showed that mechanical compression decreased the capillary barrier effect, and resulted in a 10% increase in soil moisture content near the surface. This study evaluates the impact this increase in moisture content had on moss productivity and carbon dioxide exchange (CO₂) over the growing season. In January 2016 two fields at the Bois-des-Bel peatland, were compressed using a John Deere Tractor to apply the necessary force. During the 2016 growing season (May-August), CO₂ flux measurements were taken using the closed chamber technique to characterize Sphagnum moss CO₂ exchange. Round collars were installed in the compressed fields (n=18), an adjacent uncompressed field (n=6), and an undisturbed peatland nearby (n=3). Water table and capitulum water content (fresh weight /dry weight) measurements were taken in conjunction with each flux measurement. Capitulum water content in the compressed area (average = 10.9) was significantly higher than the uncompressed (average = 8.3); however, it remained significantly lower than the natural peatland (average = 14.2; p 0.01, Kruskal-Wallis one way ANOVA on ranks & Dunn's Method). Despite the increase in water content, moss productivity was not significantly higher than the uncompressed (P 0.01, Kruskal-Wallis one way ANOVA on ranks). Further, respiration significantly increased in the compressed fields (P 0.01, Kruskal-Wallis one way ANOVA on ranks), causing the compressed area to be a slightly stronger CO₂ source vs. the uncompressed.

Preferred Platform: Oral Presentation

Student Presenter: Y

Laboratory-scale examination of the fate and transport of benzene in peat columns and their variations with depth

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Hydrocarbon spills might threaten the peatlands located nearby hydrocarbon transportation corridors; however, the fate and transport of organic contaminants in peat has received little attention, and there is insufficient knowledge of parameters governing their mobility. For example, BTEX compounds are both highly soluble and toxic; their mobility will be constrained by adsorption to peat, but the exchange capacity of peat for them is not well documented. To fill this data gap, chloride (as a non-adsorptive tracer) and benzene (one of the BTEX) solutions were pumped through peat columns and their breakthrough curves (BTCs) were obtained. Symmetric chloride BTCs showed that both solutes entered both mobile and immobile pore regions to establish physical equilibrium; entry into immobile regions is by diffusion. Therefore, the asymmetries in BTCs of benzene were attributed to the chemical non-equilibrium in adsorption of benzene. The observed BTCs were used in inverse modelling to determine unknown or uncertain parameters controlling the fate and transport of dissolved benzene, and their variations down the peat profile. Inverse modelling done using HYDRUS coupled with a global search algorithm programmed in MATLAB showed that the variations of dispersivity correlate with variations of pore size distribution. First order adsorption kinetics rates of benzene showed that the adsorption is almost instantaneous in poorly decomposed peat from near the surface. However, at 10-30cm below surface the adsorption was not instantaneous, such that the retardation factor was less than those calculated using the adsorption coefficient. The results also suggest that the retardation factor increases with depth and degree of peat decomposition. The downward increase of the retardation factor coupled with the typically lower hydraulic conductivity at depth, magnify the effect of more rapid transport of organic contaminants in near-surface peat, compared to that in deeper peat layers.

Preferred Platform: Oral Presentation

Student Presenter: Y

Multi-decadal carbon sequestration in a headwater boreal lake

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Dissolved organic carbon (DOC) in a typical headwater boreal lake at the IISD Experimental Lakes Area (Ontario, Canada) has been measured continuously since 1970. Mass balanced accounting of DOC concentrations in precipitation, watershed runoff, and inflow and outflow streams and integrated weekly hydrological data determined annual mass flux of DOC to and from the lake. Inputs minus outputs represented two residual terms; mineralization and evasion of CO₂ and DOC flocculation and sediment burial; each confirmed using an independent method. CO₂ evasion was estimated using under-ice accumulation of dissolved inorganic carbon. Accumulation of organic carbon in sediment cores estimated permanent storage. Independent measurements were similar to those calculated by subtraction of the residuals over 40-yrs. Terrestrial sources accounted for 92±1% of DOC load; 37±2% of which was lost via the outflow. Averaging values estimated by independent measurements and those via subtraction from retention, showed 48±2% of DOC load accumulated in sediments and 15±1% was lost as CO₂. Over 40-yrs, C sequestration in sediments was a more important sink than evasion or outflow. We compared the fate of DOC during decade long periods of differing precipitation patterns. Loading and loss via the outflow was higher in wet (1990-2010) compared to dry (1980-1990) years. In wet years, proportionally less DOC was buried (44±2%) and more evaded (20±5%) compared to dry years (buried = 56±3%, evaded = 11±3%) suggesting that if drought increases in boreal forests, the efficiency of headwater lakes to sequester C in sediments will be greater than in wet periods.

Preferred Platform: Oral Presentation

Student Presenter: n

An ombrogenous bog in the Hudson Bay Lowland demonstrates resilience to short-term drainage

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The vast peatlands of the Hudson Bay Lowland (HBL) extend over 240,000 km² and are globally important carbon (C) stores. Climate change poses a significant risk to the ecohydrological and biogeochemical function of the HBL peatlands, which are also at risk due to land-use change and disturbance from existing and proposed economic development (e.g. mining and transportation) within this remote region. The long-term stability of northern peatlands is facilitated by autogenic feedbacks among biological and hydrological processes. Drier conditions and lower water tables associated with climate change or infrastructure development may test this resilience, with shifts in ecosystem state likely to occur if environmental thresholds are passed. Here we compare the structure and biogeochemical function of two ombrogenous bogs in the HBL - a pristine bog (MOE) and a bog subject to ~ 7 years of gradual drainage (NRB). We found vegetation response to hydrological change differed among microforms, with no significant differences in species composition for hummocks and intermediate microforms at NRB compared with the same microforms at MOE. Dry pools at NRB comprise mostly bare peat and litter, in stark contrast to Sphagnum- and sedge-dominated pools at MOE. Net ecosystem production (NEP) was negative (i.e. C emission) for these dry pools, but despite smaller production, NEP for hummocks and intermediate microforms was positive, indicating large areas of the drained site likely remain a small C sink. Although NRB has been drained for ~ 7 years, our results did not indicate significantly advanced decomposition of peat. Our results indicate that except for dry pools, hydrological thresholds for a shift in ecosystem state have not yet been reached at NRB, highlighting the resilience of these peatlands to lower water tables and drier surface conditions.

Preferred Platform: Oral Presentation

Student Presenter: N

Potential Implication of Exogenous Nutrient Inputs from Oil Sands Operations on the Nutrient Balance and Carbon Storage of Western Boreal Peatlands

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Peatlands store carbon (C), and major nutrients (e.g. nitrogen [N] and phosphorus [P]), which are modified under exogenous nutrient inputs due to alterations in stoichiometric balance between C and nutrients. To understand the potential implications of exogenous nutrient inputs on the nutrient balance and C storage of peatlands within the industrial development hub of the Athabasca oil sands region (AOSR), we examined relationships between nutrient availability, stoichiometric balance and C storage in the soil-plant system among fens that are typical of the region. Results show that CNP ratios of peat increased from mineral-rich (C:N = 28; C:P = 86) to mineral-poor fens (C:N = 82; C:P = 1061), and from hollow to hummocks within fens. The gradient observed in peat was linked with hydrology and geochemistry, where drier and more mineral-rich wetlands had higher NP ratios. However, CNP within the vegetation are not related to those of peat. Most plants show N limitation (N:P 14:1), but industrial disturbance altered the nature of nutrient limitations in vegetation, and CNP ratios of peat and groundwater. Long-term exogenous N inputs in this region could lead to C storage in mineral-poor but not in mineral-rich fens due to differences in vegetation, hydrology and geochemistry.

Preferred Platform: Oral Presentation

Student Presenter: N

Quantification of watershed-to-stream total mercury connectivity using a new mathematical framework

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Understanding the hydrological and biogeochemical controls on mercury mobility in terrestrial upland and wetland landscapes is imperative for accurately simulating watershed mercury inputs to aquatic ecosystems, but is complicated by landscape heterogeneity. Within the hydrological community, the concept of connectivity is viewed as an organizing principle that underlies landscape complexity. While less explicitly, many approaches to understanding diffuse pollution risk have also included a basic representation of the effect of connectivity. Recently, a cohesive mathematical framework to quantify the occurrence, frequency, duration, and magnitude of both hydrologic and water-mediated material connectivity has been proposed to bring these concepts together. Here, we apply the framework to a small headwater catchment in northwestern Ontario, Canada to assess the connectivity of total mercury (THg) between an individual catchment source point and the perennial stream that drains the catchment. Using a temporally rich hydrometric and water chemistry data set previously collected at the site, our results show that over a 27 week study period in 2008, the frequency and duration of THg connectivity was 0.78 and 21 weeks, respectively. Loss of THg connectivity was mainly driven by a loss of water connectivity due to increases in detention and depression storage in a terminal wetland along the flow path of interest. When THg connectivity did occur between the watershed point of interest and the stream, the proportion of THg mobilized from the source point that connected to the stream was relatively constant at 50%. This case study illustrates that by providing a means to detect and quantify the water-mediated connectivity of material, such as THg, across different landscape units, this framework could be useful for site inter-comparisons, as well as have the potential to inform environmental policy and management decisions that are dependent on quantifying connectivity.

Preferred Platform: Oral Presentation

Student Presenter: N

Carbon and Water Fluxes During the Development of a Reclaimed Post-oil Sands Landscape

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Understanding current and future water and carbon (C) requirements of a system is vital to constructing reclaimed wetland ecosystems. This study provides a temporal snapshot of a 32 ha constructed wetland in the Athabasca Oil Sands Region. Here, C exchange and water use during the first five years of ecosystem evolution (2013-2017) are quantified using growing season measurements taken annual by eddy covariance systems located in the Fen and Upland. Results indicate a trend in C dynamics particularly associated with the establishment of vegetation. The fen quickly evolved from a C source in 2013 to a sink by 2015 as indicated by values of net ecosystem productivity (NEP: 124, -41, -229 gCm⁻²year⁻¹) and gross ecosystem productivity (GEP:-559, 1081, -1094 gC m⁻²year⁻¹). As vegetation became well established (2015), GEP and NEP have remained relatively constant. Evapotranspiration rates between 2013 and 2017 show a decreasing trend with values of 2.95 2.46 2.72, 3.5 and 2.27 mm day⁻¹. Similarly, water use efficiency (WUE) has steadily increased from 1.40 gC kg H₂O⁻¹ m⁻² day⁻¹ in 2013 to 3.11 gC kg H₂O⁻¹ m⁻² day⁻¹ in 2017. ET and WUE trends are attributed to the decrease in ponded areas associated with the expansion and increased density of vegetation. The treed upland has developed at a slower rate than the sedge-dominated fen with results indicating a net C loss (NEP: 4.46, 2.43, 2.49, 0.87, 1.12 gC m⁻²year⁻¹; GEP: -2.34; -4.09, -2.74; -3.65; -4.16 gC m⁻²year⁻¹) with the trajectory towards become a net C sink within the next 1-3 years as vegetation matures. ET has been relatively constant (ranging from 145-211 mm day⁻¹) however, since 2015, ET rates have exceed precipitation indicating that vegetation has become interconnected to the groundwater network and no longer dependant solely on precipitation. Overall, water and C fluxes of both landscapes are expected to stabilize and future fluctuations are predicted to be controlled by meteorological influences.

Preferred Platform: Oral Presentation

Student Presenter: Y

Impact of seismic lines on boreal peatland methane emissions

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Peatlands cover ~30% of Canada's boreal region where resource exploration and extraction creates a patchwork of disturbance across the landscape. Mapping of underlying geology requires seismic exploration and has created a grid of cleared lines (i.e., seismic lines), many of which also cross peatlands where they are slow to recover. Clearing trees and passage of heavy equipment can result in flattening of the ground surface on the seismic line, shallower water table position and warmer soils. Saturated soils in peatland ecosystems allows for the production and emission of the greenhouse gas methane (CH₄), while warmer, wetter conditions on seismic lines likely enhance these emissions. We measured CH₄ flux on a series of peatland seismic lines in the province of Alberta and compared these to flux in the adjacent peatland. We also used unmanned aerial vehicles (UAVs) to map peatland surface elevation, determine shifts in water table position on seismic lines and estimate the impact on C H₄ emissions. In general, seismic lines became flatter, wetter and had warmer soil temperatures resulting in higher CH₄ emissions; however, the extent of the increase in CH₄ emission was site specific. Given that at least 345,000 km of seismic lines cross peatlands in the province of Alberta, this represents a significant anthropogenic greenhouse gas emission that is not currently well-constrained. More research on seismic lines with varying characteristics is needed to improve our understanding of controls on local changes in CH₄ flux in order to improve estimates of the impact on regional scale emissions.

Preferred Platform: Oral Presentation

Student Presenter: N

**Greenhouse gas fluxes and carbon storage functions in two contrasting fen-peatland types:
Implications for global warming**

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Northern peatlands are long-term, stable carbon (C) sinks due to slow decomposition rates under a normally cool and wet environment. However, the C stored in northern peatlands is sensitive to environmental disturbance such as increased temperature. Thus, how the C storage function of northern peatlands will change in response to climate change is of significant interest. Sphagnum-dominated poor fens and sedge-dominated intermediate fens are two prevailing peatland types in Canada, yet there is much less C balance data for these fen-peatlands than for ombrotrophic bogs. In this study, we are using a unique field experiment with a replicated factorial design to experimentally examine the effects of increased ground temperature and elevated atmospheric carbon dioxide on above- and belowground ecosystem processes, including greenhouse gas fluxes (carbon dioxide and methane) in two contrasting fen-peatland types. Here, we present carbon dioxide and methane flux, and mass balance data over two growing seasons in 2016 and 2017 prior to the initiation of active warming. Our results show that overall the Sphagnum-dominated fen stored ~23% more C than the sedge-dominated fen. Methane fluxes in the sedge-dominated fen are most strongly controlled by water table depth and plant productivity, whereas temperature is a stronger control on the Sphagnum-dominated fen methane fluxes, with no significant influence of plant productivity. Calculated global warming potentials (GWP) showed that the Sphagnum-dominated and sedge-dominated fens had net cooling effects to the atmosphere, with the cooling effect of the Sphagnum-dominated fen being between 25 and 50% greater than that of the sedge fen. These results highlight the need to fully understand the controls on greenhouse gas balance among fen peatland types in order to better model the feedbacks between ecosystems and climate change.

Preferred Platform: Oral Presentation

Student Presenter: Y

Post Wildfire Burn Severity in Peatlands Effect on Carbon Exchange

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Northern peatlands store carbon under cool and wet climates that allow for plant productivity rates to exceed decomposition, containing nearly one-third of terrestrial soil carbon. However, these peatlands are vulnerable to the increasing rates of high magnitude forest fires in the boreal region, putting into question the ability of peatlands to remain a C sink. Forest fires that spread from upland forests to peatlands can cause a mass release of C to the atmosphere, yet the trajectory of recovery and fire effects on variables affecting C storage is poorly understood. Poplar Creek Fen, a moderately-rich fen in Fort McMurray was burned during the Horse River Wildfire in early May of 2016 and is being studied to address the C functionality by comparing unburned, control areas, to those areas completely burned by the fire. Carbon uptake in the burn sites is shown to still be productive post-fire, although it is weaker than the control sites. Burned carbon uptake follows a similar trend of the control sites with the highest uptake occurring in the middle of the growing season and hummocks remaining as carbons sinks throughout the season, whereas hollows in the late season become carbon sources. There is distinct variability seen in the potential controls of carbon uptake over the growing season. It is shown that in the burned sites there is significant correlation between the net ecosystem exchange (NEE) and the variables related to burn, such as depth of burn, regrowth of vegetation and soil nutrients that are elevated due to the ash addition. In contrast, at the control sites water table has the most significant correlation with NEE. This difference in correlating factors of carbon uptake could be helpful in the long-term, to the evaluation of recovery and indicators of normal functionality.

Preferred Platform: Oral Presentation

Student Presenter: Y

Conceptualizing the Role of Seasonal Ground Ice in a Western Boreal Plains Peatland

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Peatlands within the Western Boreal Plains act as an important water source for the surrounding landscape, and can persist despite the presence of a sub-humid climate. The annual freezing and melting of seasonal ground ice (SGI) is hypothesized to be one of the mechanisms behind peatland persistence and a contributor of water within peatlands and the landscape. However, the eco-hydrological role of SGI has not been studied within the context of the WBP. This study elucidates the ecohydrological role of SGI in a poor fen peatland, quantifying the impacts on near surface water availability and the surface energy balance. 240 SGI survey points were measured once a week during the 2017 spring melt, geolocated, and interpolated using an inverse distance weighting method. Soil moisture (0-5cm) was measured at every other survey point while water table position was manually measured at 20 wells throughout the study site. Results showed that the presence of SGI within 30 cm of the surface created a perched water table within 10-15cm of the surface and high near surface moisture conditions (60-90% 0-5cm layer). These conditions were created when water from snow melt was unable to infiltrate while melting SGI contributed water to the surface. SGI equaled 248.93 mm for the spring, with approximately 122.75 mm made available within 30 cm of the surface during the first two weeks of melting. Thus, peatland surface vegetation had an adequate water supply while the peatland could potentially act as an early source of water for the surrounding uplands. This mechanism may be important for particularly dry springs when precipitation is low and the snowpack is thin. The presence of melting ice reduced the available energy at the surface, which reduced spring evapotranspiration rates by 18% . The results of this study support the hypothesis that SGI can play an important role in peatland persistence and its ability to act as a water source during the spring season.

Preferred Platform: Oral Presentation

Student Presenter: Y

Environmental controls on CO₂ exchange along a salinity gradient in a saline boreal fen in the Athabasca Oil Sands Region

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Saline boreal fens, serve as potentially appropriate natural analogs for peatland reclamation in areas affected by salinization in the Athabasca Oil Sands Region. Thus, understanding the controls on carbon dioxide (CO₂) exchange within these natural systems can provide insights into the biogeochemical and carbon sink functioning of constructed wetlands under saline conditions. As such, we assessed net ecosystem exchange, ecosystem respiration, and gross primary productivity of peatland and open-water areas within a saline boreal fen near Fort McMurray (Alberta, Canada) to determine environmental controls on CO₂ fluxes using community-scale CO₂ measurements along a salinity gradient. Vegetation properties, water table depth, and electrical conductivity were identified as the main controlling factors on carbon capture within the peatland. Additional drivers of carbon uptake (e.g., soil moisture, availability of magnesium, manganese and calcium) were found within depressions suggesting that microtopographical differences can modify relations between CO₂ exchange and environmental variables. Within open-water areas, carbon uptake was driven by vegetation density and phosphate concentration. This study has revealed the importance of development of appropriate planting schemes for peatlands and ponds to achieve sustainable CO₂ uptake within constructed fens, which may be challenged by conditions of increased salinity.

Preferred Platform: Oral Presentation

Student Presenter: Y

Peat water repellency as an indicator of post-wildfire peatland ecohydrological resiliency

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Boreal peatlands may be vulnerable to projected changes in the wildfire regime under future climates. Extreme drying during the sensitive post-fire period may exceed peatland ecohydrological resilience, triggering long-term degradation of these globally significant carbon stocks. Despite these concerns, our research has demonstrated that low peatland evapotranspiration at both the plot and landscape scale tends to occur post-fire in water-limited peatlands dominated by feather moss that are ubiquitous across continental western Canada. Low post-fire evapotranspiration enhances the resilience of peat carbon stocks and reinforces their function as a regional source of water. We suggest that near-surface water repellency represents an important regulator of peatland evapotranspiration that can induce low evapotranspiration in the initial post-fire years by restricting the supply of water to the peat surface. However, extreme future wildfires may exceed this feedback response and instead enhance drying and induce instability in peatland carbon stocks. Correspondingly, our research has also demonstrated that extreme burn severities increased post-fire evapotranspiration by over 400% within a feather moss peatland. The fire burned through the protective capping layer that restricts evaporative drying in response to traditional (low-severity) burns. As such, we test the concept of using peat water repellency as an indicator of post-wildfire resiliency. We took advantage of the burning of a drained peatland in the 2016 Fort McMurray Horse River wildfire. Water repellency, using the water drop penetration test, and peat burn severity were measured at undrained, moderately drained and heavily drained treatments (analogous to moderate to severe responses to climate change predictions). We demonstrate that extreme wildfires burn through the water repellent cap leaving peatlands unprotected and more vulnerable to intense post-fire drying, inducing high rates of carbon loss to the atmosphere that amplify direct combustion emissions.

Preferred Platform: Oral Presentation

Student Presenter: N

Spatially-integrated estimates of carbon dioxide and methane fluxes from Canadian peatlands

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Peatlands are an important component of Canada's landscape, however there is little information on their national-scale net flux of carbon dioxide and methane. This study compiled results for non-permafrost peatland fluxes from chamber and eddy covariance studies across Canada. The data were summarized by bog, poor fen and rich-intermediate fen categories for the seven major peatland-containing terrestrial ecozones (Taiga Plains, Taiga Shield, Boreal Shield, Atlantic Maritime, Mixedwood Plains, Boreal Plains and Hudson Plains) that comprise 96% of all peatlands nationally. An improved peatlands map was created from forest composition and structure information that distinguishes bog from rich and poor fen at 250 m resolution. National Forest Inventory k-NN forest structure maps, bioclimatic variables and ground surface slope were used to delineate the treed and forested peatlands and the EOSD map of wetlands was used to identify open peatlands with minor tree cover. The new map was combined with averages of observed carbon dioxide and methane fluxes to estimate a growing season greenhouse gas (GHG) balance for the seven ecozones (excluding fire emissions). This analysis improves upon previous basic, aspatial estimates and discusses the potential sources of the high uncertainty in spatially integrated emissions which indicates a need for refined maps of peatland distribution for national carbon emissions estimates. The next step in improving national GHG balance estimates is the ongoing development of the Canadian Model for Peatlands (CaMP), intended to simulate carbon stock changes and emissions for nine peatland categories over contemporary (1990 to present) and future (10 to 100 years ahead) time frames. The CaMP will be a module of the next generation modeling framework of the Carbon Budget Model of the Canadian Forest Sector and is designed for spatially-explicit application at multiple scales from sites to a national scope.

Preferred Platform: Oral Presentation

Student Presenter: N

Water table drawdown as a surrogate for climate change: 15 years later

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Northern peatlands represent significant global soil carbon sinks and understanding how these systems may respond to climate change is critical. Climate models suggest a warmer climate for northern latitudes resulting in a water table decrease of ~20 cm. In 2002 a pond (Experimental) in a patterned fen near Quebec City was drained, simulating climate change. The results predicted that the surface of the peatland would flatten due to differing carbon accumulation rates between high (more oxidation) and low points (more accumulation), and that hydraulic conductivity would decrease with increased decay. We revisited the site 15 years later to assess our predictions. A topographic survey showed a higher standard deviation (16.6 cm) in the Control pond (undrained) in surface elevations vs. Experimental pond (14.5 cm), suggesting a flatter landscape. Hydraulic conductivity was between 1 and 3 orders of magnitude lower from 2002 to 2017 at Experimental, but only half at Control.

Preferred Platform: Oral Presentation

Student Presenter: N

Seasonal variation of arsenic and antimony in surface waters of small subarctic lakes impacted by legacy mining pollution near Yellowknife, NT

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The early years of historical mining activities in the Yellowknife region resulted in the release of large amounts of arsenic (As), antimony (Sb), and metals to the surrounding area. Fifty years after the bulk of these emissions were deposited, surface waters of many local lakes continue to exhibit elevated concentrations of contaminants, particularly As and Sb. The seasonal variation in surface water As and Sb concentration was assessed in four small (1.5 km²) subarctic lakes impacted by emissions from legacy mining activities. Substantial seasonal variation in surface water As concentrations were measured in all but the deepest lake ([As]: 27-40 µg/L; maximum depth 6.9 m), including a four-fold difference in surface water As in the shallowest lake ([As]: 172-846 µg/L; maximum depth 0.8 m). The development of an ice-cover enriched surface water concentrations of As in the three shallowest lakes (50-100%) through a combination of physical and biogeochemical processes. Early winter increases in As were associated with the exclusion of solutes from the developing ice-cover, whereas large increases in surface water As were measured once oxygen conditions were depleted to the point of anoxia by mid-winter, and were associated with large increases in iron (Fe) and manganese (Mn), suggesting coupling of As mobility with Fe and Mn cycling. In contrast, seasonal variation in surface water Sb was not associated with Fe cycling and anoxia. These observations highlight the contrasting geochemical behaviour of As and Sb in lacustrine environments and demonstrate the importance of considering winter conditions in evaluating the long-term fate of As and Sb in shallow lakes with a long ice-cover season. The annual remobilization of sediment As into overlying waters under ice may be a significant process inhibiting the long-term chemical recovery of shallow lakes in the region and should be considered when evaluating exposure of aquatic life to legacy As.

Preferred Platform: Oral Presentation

Student Presenter: Y

Effect of soil moisture on C:N:P ratios of wetland shrubs

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The stoichiometric relationships of carbon (C), nitrogen (N), and phosphorus (P) in plants have a strong control on fitness, fecundity, and resistance to herbivory. The C:N:P dynamics of plant tissues also influence rates of decomposition and nutrient fluxes back into the soil environment. While much is known about these relationships in graminoid and herbaceous wetland species, there currently is next to no information on wetland shrub thicket species. This study investigates the C:N:P ratios of seven shrub species and two goldenrods grown under contrasting soil moisture regimes. Plants were grown in the field for one growing season in low-, medium-, and high-soil moisture. Shrub roots, stems, and leaves were tested separately for C, N, and P contents. Stems had very high C:N and C:P ratios, and were not related to soil moisture content. Ratios in root tissue deviated from Redfield ratio expectations (108:16:1) with particularly strong N-limitation. Soil moisture had varying responses to leaf tissue C:N:P dynamics between species. *Spirea alba* growth in the high soil moisture treatment outpaced N acquisition, leading to C:N ratios 40:1. On the other hand, *Rosa palustris*, which had the same growth response to high moisture, maintained C:N:P ratios between soil moisture treatments. *Salix discolor* and *Cornus sericea* leaf tissue N:P ratios were lowest in the medium-soil moisture treatment, demonstrating greater P-scavenging at this moisture treatment. Results of this study demonstrate a range of C, N, and P acquisition abilities between species of a similar plant functional type; however, the wetland shrubs studied here ubiquitously show higher C:N and C:P ratios than other wetland plant functional types.

Preferred Platform: Poster Presentation

Student Presenter: N

Pore-water Feedbacks and Resilience in Peat-filled Bedrock Depressions of the Canadian Shield

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Northern peatlands persist on the landscape owing to hydrological feedbacks that confer resilience to disturbances such as moisture deficits. One feedback involves pore-water residence time and decomposition, whereby changing peat hydrophysical properties facilitate the accumulation of decay end-products deep in the peatland profile that thermodynamically suppress further decomposition. A simplified model of pore-water residence time suggested reduced turnover in deep layers of larger hypothetical peatlands, conferring resilience via this feedback. Because this has not been well-observed in natural systems, peat-filled depressions (PFDs) found in the Canadian Shield rock barrens landscape of Central Ontario were selected to explore this feedback on a smaller scale. These PFDs store carbon and serve as critical habitat for at-risk reptiles, so it has become increasingly important to assess their resilience and restoration potential in the face of pressures from human development and climate change. Piezometers were installed in nine PFDs in order to develop profiles of pore-water isotopic composition (δD and $\delta^{18}O$) sampled weekly and dissolved organic matter (DOM) properties sampled monthly from May to August 2017. Profiles were measured in two microforms for each depression at a resolution of 20 cm and paired with cores to assess peat properties and carbon accumulation. PFD sizes ranged from 0.02 to 1.25 ha in area and depths of about 0.6 to 2 m. A Picarro CRDS isotopic analyzer was used to analyze pore-water, rainfall and outflow samples collected throughout the season. Rainfall samples were used to develop a Local Meteoric Water Line and with the pore-water profiles to estimate the residence time at different depths. DOM was analyzed on an Aqualog spectrofluorometer in order to calculate indices of DOM character. Results of this work will be presented to explore the importance of peat thickness in controlling peat ecosystem resilience.

Preferred Platform: Poster Presentation

Student Presenter: Y

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

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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.

Preferred Platform: Poster Presentation

Student Presenter: N

Temporal and spatial variability in the DOC dynamics of a constructed wetland in the Athabasca Oil Sands Region

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In the Western Boreal Plain, fens comprise up to 50% of the landscape. However, much of this region has been disturbed due to bitumen extraction in the Athabasca Oil Sands Region. To restore equivalent land capability, fen construction has been performed to test reclamation techniques in sub-humid climate. A component of the carbon budget within peatlands is the export of dissolved organic carbon (DOC), which varies in its biogeochemical properties depending on the abiotic and biotic conditions under which it has formed. As DOC has been shown to represent up to 20% of the carbon budget in peatlands, and can have significant impacts on water quality, it is important to monitor the amount of DOC present within constructed systems, potential sources, and temporal evolution. In this study, DOC concentration and fluorescent dissolved organic matter (FDOM) quality were monitored for six years post-construction at the Sandhill Fen in Fort McMurray, AB. Fluorescence index values remained below 1.6 in all years, suggesting that plant sources dominated DOC inputs following early vascular vegetation establishment. In 2017, SUVA₂₅₄ increased compared to previous years, with a corresponding decrease in β/α , indicative of an increasing influence of microbial activity on DOC and FDOM. Spatial influences were also evident; humification and freshness index were consistently lower and higher, respectively, in the western portion of the fen, compared to the central and eastern monitoring locations. Results indicate that early vegetation success largely controls DOC dynamics within this constructed fen; however, localized fen conditions can create variable DOC quality. As the Sandhill Fen is strongly managed at this time, exports of DOC are small, yet when integrated into the surrounding landscape will be a significant component of the carbon balance.

Preferred Platform: Poster Presentation

Student Presenter: N

Enduring effects of topographic constraints on peat development in a beaver-inhabited montane fen

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Carbon storage estimates from multi-proxy, paleo-reconstruction typically assume a uniform peatland represented by a solitary core. Rarely are multiple cores extracted from separate locations in the same peatland, where peat evolution varies because of different external pressures. Our goal was to bring insight into why peat accumulates more in some areas than in others, and describe the soil forming factors and processes responsible for such spatial complexity. We extracted three cores from a montane fen, each representing different local environments in terms of plant community, hydrology, and peat depth. The cores were extracted from a beaver meadow, a riparian area, and a fen, away from a local stream. Testate amoebae were used to group core samples according to different environmental conditions, as interpreted through biotic and abiotic proxies. Topographic position and proximity to surface water features largely explained differences in peat initiation timing and development between sites. That said, regional climate exerted a primary control on peat properties and its biota, as synchronous shifts between dry and wet intervals were found across all three sites. The least amount of peat accumulated in the beaver meadow, where peat initiation was delayed and frequent inundation encouraged sediment deposits that enhanced turnover rates during dry periods. Turnover was also high in the riparian area, where high biogeochemical activity and unstable hydrology favored the growth of herbaceous vegetation that was easily decomposed. Peat accumulation was highest in the fen, where peat initiated sooner and strong internal feedbacks facilitated a relatively stable hydrology over time.

Preferred Platform: Poster Presentation

Student Presenter: Y

Methyl and total mercury export dynamics in a peatland following enhanced atmospheric sulphate additions

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Atmospheric deposition of sulfate (SO₄) has been linked to enhanced mercury methylation in peatlands; however, since the enactment of the Clean Air Act, atmospheric SO₄ deposition to peatlands in the US Midwest has significantly declined. In-situ peatland biogeochemical processes linking sulphur, mercury biogeochemistry and hydrology are relatively well understood, but there remains no information on methylmercury (MeHg) or total mercury (THg) export from peatland-dominated watersheds as SO₄ deposition declines. Here, we present results from a multi-year, ecosystem-scale experiment at the Marcell Experimental Forest wherein SO₄ deposition was increased and then brought back to current natural deposition levels over two sequences. The response in flow-weighted mercury (both MeHg and THg) export dynamics was monitored in the surface water outlet through the entirety of the experiment. In the first phase of decreasing sulphate deposition (2006 – 2008), SO₄ inputs were shutoff in half of the experimentally manipulated peatland area furthest from the outlet but no distinguishable effect on MeHg export was detected at the outlet; suggesting the majority of the MeHg detected was produced within the remaining active SO₄ input region. Within two years of ceasing all excess SO₄ inputs (second phase: 2008 – 2010), the annual MeHg export from the peatland was approaching that of a nearby reference peatland. Conversely, the daily THg export remained elevated, typically by an order of magnitude. However, the total annual export of both MeHg and THg was similar between the experimental and reference sites due to temporal variations in volumetric flux between the two sites. This study clearly illustrates the rapid (within two years) return to natural mercury export following large decreases in SO₄ deposition, suggesting relatively rapid declines in MeHg export from peatlands may have contributed to decreasing MeHg levels in the region following implementation of the Clean Air Act.

Preferred Platform: Poster Presentation

Student Presenter: N

Development and validation of a column model for methane production, consumption and release in northern wetlands

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Wetlands represent a considerable land cover type of the boreal and Arctic regions where permafrost also prevails. These waterlogged environments store a substantial amount of soil organic matter, which could decompose partially into methane and lead to substantial methane emissions into the atmosphere once the underlying permafrost thaws. As these methane emissions constitute a significant part of the permafrost carbon feedback on climate, process-based modelling of associated biogeochemical mechanisms is required to better investigate their contribution to future surface warming, which is still lacking in climate projections. The goal of this research is to develop a 1-D (column) model for microbial methane production, consumption and release in wetlands that will be further embedded into an Earth system model. The column model considers the vertical distribution of methane production rates in the active layer, the dynamics of methane production with water table variations, the occurrence of methane emissions under zero-curtain conditions, among other features. The model outputs are validated against site-scale observations from the boreal and Arctic regions, providing insights into the ability of the model to reproduce variations in methane production under freeze-thaw cycles, growing season methane emissions as well as cold season methane emissions. Furthermore, this modelling work explores the sensitivity of methane emissions to possible warming trends and soil moisture changes in the northern high-latitudes. The ultimate goal of this research is to quantify methane emissions associated with the projected thawing of permafrost in northern wetlands and the subsequent feedback on the global climate.

Preferred Platform: Poster Presentation

Student Presenter: Y

The Role of Vascular Vegetation on Carbon and Water Dynamics in a Constructed Peatland.

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As wetlands comprise approximately half of the pre-disturbance landscape in the Athabasca Oil Sands Region, a peatland fen was constructed in the attempt to create a self-sustaining ecosystem that is carbon-accumulating and capable of supporting a representative assemblage of species. The availability and use of water throughout the ecosystem is critical to successful system evolution and is controlled namely by 1) storage capacity of soils and 2) vegetation. Whereas the water holding capacity of soil has been well studied in the oil sands context, there is less understanding as to how regenerating plants along their succession pathways use water. Thus, water use efficiency (WUE), which links photosynthesis with water use, provides a useful metric to evaluate the utilization of water and carbon resources. This study examines the carbon and water dynamics of *Carex aquatilis*, *Juncus Balticus* and *Typha latifolia* in a constructed peatland. Plot-based, chamber measurements of carbon fluxes along with detailed vegetation surveys were conducted during the 2017 growing season at 30 60 x 60 cm² plots. Wells were installed at each plot to establish water table fluctuations and water availability in the rooting zone. Results indicate that the constructed site is sequestering C and acting as a net sink. Gross ecosystem productivity (GEP) and net ecosystem productivity (NEP) was greatest during peak season in all three plant types. *C. aquatilis* and *T. latifolia* show similar values throughout the season for GEP ranging from -5 to -45 gCO₂ m⁻² day⁻¹ while GEP for *J. balticus* is greater ranging from -30 to -75 gCO₂ m⁻² day⁻¹. In terms of WUE, *C. aquatilis* typically has the highest WUE during the beginning of the growing season, while *J. balticus* has the highest overall WUE (occurring during peak season). Plots dominated by *T. latifolia* had the lowest WUE of the three plant types.

Preferred Platform: Poster Presentation

Student Presenter: Y

Controls on Autotrophic and Heterotrophic Respiration in an Ombrotrophic Bog

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Northern peatlands are globally significant carbon (C) stores, but the sink strength may vary from year-to-year. In some years, peatlands may even be C sources due to variations in climatic conditions. Peatlands cover roughly 12% of Canada's terrestrial surface, thus future changes in climate (or land use) could have an impact on Canada's overall greenhouse gas emissions. Models can project the sensitivity of peatland C balance components to climate and land-use changes. However, most models partition ecosystem respiration into its autotrophic (AR, respiration by plant parts) and heterotrophic (HR, respiration by microbial bacteria in the soil) components using poorly known and constant ratios. This partitioning approach may lead to erroneous estimates if a change favours one form of respiration over another and alters allocations of C to labile pools with different turnover rates. Additionally, obtaining direct measurements is essential to explaining the temporal and spatial dynamics of respiration. The objectives of this study are thus, to partition AR and HR at Mer Bleue, an ombrotrophic bog, using direct methods, and to determine the factors that may drive the spatial and temporal variability in AR and HR. Plot level measurements will be used to partition AR and HR (using automatic and manual chamber methods) and will be coupled with the use of stable ($\delta^{13}\text{C}$) and radioactive (^{14}C) isotopes of C through end-member analysis. This project will improve our understanding of peatland C cycling and will be useful to incorporate peatland-specific climate feedbacks in land surface schemes as well as improve the accuracy of peatland models.

Preferred Platform: Poster Presentation

Student Presenter: Y

Water Table Dynamics in a Restored Peatland on a Former Oil Well-Pad

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Well-pads are a common disturbance in the Alberta oil sands. Federal and provincial law requires some measure of restoration after site abandonment or disuse, yet research on restoration of well-pads and other associated disturbances is limited, particularly in peatland ecosystems. This study evaluates the hydrologic function of experimental treatments on a restored peatland well-pad. Study objectives include quantifying hydrological conditions on the well-pad and natural areas and observing hydrology of the well-pad within the context of the natural peatland. The field site is a 1 ha well-pad (IPAD) and surrounding natural peatland located near Peace River, Alberta. Surface layers of IPAD's clay well-pad and underlying geotextile were removed, and underlying peat was decompacted (i.e., inverted) with some of the clay pad buried under the peat to achieve the desired surface elevation. Therefore, three main restoration techniques were used: 1. Clay Inversion (clay buried under peat), 2. Peat Inversion (no clay), and 3. Mixed Clay Inversion (clay buried, but with some mixing into peat). Transects of piezometer nests (x3 piezometers of varying depths and x1 well each) were installed that crossed IPAD and extended 100 m into the natural site: two were oriented east-west and two north-south. Between June and August 2017, water table was measured up to twice a week, hydraulic conductivity was measured once at each piezometer, and elevation was determined. Three core samples were taken from each treatment and four from natural areas to investigate soil hydrophysical properties. Water table and elevation data suggests the restored site is forming a small perched water table, suggesting a hydrological disconnect between restored and natural sites. This could be due to a combination of factors including peat compression and treatment type. Differences in hydraulic conductivity between the restoration treatments and undisturbed natural areas will also be presented.

Preferred Platform: Poster Presentation

Student Presenter: Y/N

Comparing access road impacts on boreal peatlands' hydrological connections between wet and dry years

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Canada's boreal region has one of the highest densities of peatlands and is fragmented by more than 600,000 km long road network constructed to explore and extract natural resources (e.g. oil sands, forest products, etc.). Roads crossing peatlands are raised and act as dams, blocking hydrological connection between fragmented parts of the peatland. We investigated the impacts of roads on local hydrology in a forested bog and shrubby fen near Peace River, Alberta. Every week from May to August 2016 and 2017, water table (WT) position with respect to the surface was measured from wells representing all levels of three factors: 1) side of the road (upstream and downstream), 2) culvert position (2m and 20m), and 3) distance from either side of the road (2m, 6m, 20m). Result showed that the 2016 was a wet year compared to 2017. In bog, the average WT position on road disturbed areas in 2016 and 2017 were significantly higher than natural areas in 2016 and 2017, respectively. In contrast, significant differences between disturbed and natural areas were not observed in fen. However, in fen, two-way interactions of all factors were significant for predicting variation in mean WT position only in 2016. In both bog and fen, the downstream 2m and 6m areas far from culverts were significantly drier compare to other areas in 2016. In contrast, in 2017, only 2 m areas far from culverts remained significantly drier in bog, but no such variation was observed in fen. In conclusion, both bog and fen showed WT position variation within road-disturbed areas in a wet year, but in a dry year road effects were only observed at the bog. Differences are likely due to slope direction that was perpendicular to the road in the bog, but parallel to the road in fen. The hydrological variation may also lead to the variations in impacts on GHG emissions, plant growth and functions, microbial activity, and soil biogeochemistry between dry and wet years requiring further investigation.

Preferred Platform: Poster Presentation

Student Presenter: Y

Use of Wetland-to-Lake Hydrologic Connectivity Metrics to Better Understand Broad-Scale Patterns in Lake Dissolved Organic Carbon Concentrations

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Wetlands that are hydrologically connected to downstream receiving waters can act as sources of dissolved organic carbon (DOC) and toxic methyl mercury (MeHg). In some systems, DOC concentration is a strong predictor for total mercury and MeHg concentrations in water due to the affinity of Hg to bind to reduced sulfur groups on the DOC. Wetlands are known as hotspots for the production of MeHg and while previous studies have shown that the percentage of wetland area within a watershed is related to downstream MeHg levels, variability in this relationship may be due to a lack of hydrologic connectivity between wetlands and downstream receiving waters. To better understand the influence of watershed characteristics, such as wetland coverage, on the fate and transport of MeHg in freshwater systems, the goal of this study is to assess the extent to which inclusion of wetland-to-lake connectivity metrics improves predictive models of lake water chemistry, in particular DOC concentrations. We make use of a broad-scale lake chemistry dataset collected and maintained by the Province of Ontario, the provincial 30m digital elevation model, and the wetland class from the provincial land cover layer to examine the spatial relationships between wetland-to-lake connectivity and lake chemistry. Using a GIS approach, wetland-to-lake connectivity metrics such as, mean flow path distance, mean flow path slope, wetland landscape position were calculated for 69 headwater lake catchments. Linear regression was used to assess the relationship between individual connectivity metrics and lake DOC concentrations and stepwise linear regression was used to assess the potential for multiple landscape and connectivity metrics to improve on the traditional wetland area to DOC concentration relationship. Understanding how hydrologic connectivity of wetlands to downstream lakes influences lake DOC concentrations will improve our understanding of broad-scale patterns in lake Hg levels.

Preferred Platform: Poster Presentation

Student Presenter: Y

CGU_H_09: Coupled Hydrological and Biogeochemical Functions, Part II: Terrestrial Ecosystems

Conveners: Fereidoun Rezanezhad¹, Colin McCarter^{1,2}, Tobias Weber³, Merrin Macrae⁴, Nandita Basu¹, Philippe Van Cappellen¹

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Isotopic insights into organic matter transport and transformation across hydrological interfaces in a temperate forest catchment

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Soils and sediments are important long-term reservoirs of carbon in terrestrial ecosystems, but we have a limited understanding of the connectivity between these reservoirs. Isotope measurements (^{13}C , ^{14}C , ^{15}N) provide a tracer for organic matter (OM) sources that can be used to understand connections between soil and sediment carbon. In this study we sampled plant, soil, algae, and sediment samples across a forest catchment at Mont St. Hilaire, Quebec, and analyzed their carbon and nitrogen isotope ratios. These data provide holistic insights into the transport of OM across hydrological interfaces between soils, streams, and lake sediments. Soil and litter $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values are positively correlated, with enrichment in both ^{13}C and ^{15}N with soil depth. Lake and stream sediment samples deviate from this soil isotope trend, with a wide range of $\delta^{13}\text{C}$ values suggesting variable sources of OM. We observe a water depth dependence for sediment isotope values, with shallow water sediments (2 m) resembling topsoils, intermediate water sediments (2-5 m) enriched in ^{13}C and depleted in ^{15}N , and deep water sediments (5 m) depleted in ^{13}C and enriched in ^{15}N . We infer that topsoil OM is dominates shallow water sediments, while in intermediate water sediments topsoil OM is mixed with ^{13}C -enriched aquatic OM. In deep water sediments OM isotope values are likely altered by anaerobic microbial metabolisms, with methane cycling causing low $\delta^{13}\text{C}$ values. Stream and beaver pond sediments also exhibit low $\delta^{13}\text{C}$ values suggesting microbial OM reprocessing. Subsoil samples exhibit ^{14}C ages between 1000 to 2000 years BP, but lake sediment samples were modern in age. This corroborates stable isotope data suggesting that there is minimal input of subsoil carbon into sediments. Our dataset suggests that the sources of organic matter to lake sediments are spatially variable, with topsoil OM being progressively diluted with aquatic OM and recycled microbial biomass at greater water depths.

Preferred Platform: Oral Presentation

Student Presenter: N

Patterns and Controls on Dissolved Organic Carbon Dynamics during High Flow Events in Forested Catchments

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Dissolved organic carbon (DOC) is an important control on the functioning of aquatic ecosystems as it influences many parameters, including light penetration, temperature, microbial respiration, pH and mobility of metals. DOC concentration increases have been widely observed in lakes in recent years in the Northern Hemisphere but there is no consensus around the mechanisms for this increase. Recent work suggests that watershed-specific hydrologic and topographic characteristics play an important role in controlling DOC concentrations and export from forested catchments. High-flow hydrologic events, including spring melt and summer and fall rainstorms can mobilize terrestrial DOC and result in large fluxes to streams, thus routine monitoring programs might misrepresent both patterns and mechanisms of DOC export. This study examined how stream DOC quantity and quality was influenced by variability in catchment wetland coverage and hydrological conditions (e.g., storm events, spring melt). Samples were collected at a sub-daily frequency through high flow events for two years (2016 and 2017) at three boreal forested catchments. A hysteresis analysis was used to evaluate DOC transport dynamics across catchments and storms. Secondly, we used several DOC quality metrics to evaluate possible spatial and temporal variability in the nature of stream DOC between catchments. Transport dynamics varied substantially among upland catchments during summer and fall storms, but were more uniform across all catchments during the spring melt period; the wetland-dominated catchment exhibited less variability in DOC concentration across all seasons. The DOC quality metrics suggest that the source of DOC during high flow events depends on proportion and location of wetlands within the catchment. These results emphasize the importance of high frequency sampling to detect and understand impacts of changing environmental conditions on carbon dynamics in forested catchments.

Preferred Platform: Oral Presentation

Student Presenter: y

The annual base cation budget at Plastic Lake deducted from high-frequency geochemical time-series

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Here we present annual base-cation budgets for the Plastic Lake watershed near Dorset in Central Ontario. We have sampled the stream draining the largest sub-catchment (PC-1) on a daily basis and have obtained a comprehensive geochemical data set for major cations, trace-metals, water isotopes and radiogenic Sr isotopes, as well as hydrological parameters. The geochemical time-series reduces the potential effects of sampling bias and seasonal effects associated with low frequent sampling, and allows for geochemical dynamics to be observed in unprecedented detail. Our data enable us to establish elemental budgets and to gauge the magnitude of base-cation export fluxes in relation to established long-term mineral weathering rates and atmospheric inputs. Geochemical yield calculations reveal steady-state between mineral weathering and export fluxes for Na, and net storage of Si and K within the sub-catchment. For Ca and Mg, geochemical yields indicate a slight net loss over the sampling. Using long-term mineral weathering rates from [1], export fluxes exceed mineral weathering rates by 10% for Ca and up to 50% for Mg. Using more recent weathering rate estimates by [2], export rates are equal to mineral weathering. Either way, base-cation export rates are close to (or at) steady-state with respect to mineral weathering. Historically excessive base-cation leaching from soils in this area has greatly decreased over past decades. The preliminary conclusions of our time-series investigation are as follows; base-cation export is close to (or actually at) steady-state with mineral weathering. As far as Ca levels in related freshwater bodies are concerned, recent Ca levels reflect natural supply by mineral weathering, and are likely at long-term freshwater levels. [1] Kirkwood, 1991., [2] Watmough, S.A., 2003.

Preferred Platform: Oral Presentation

Student Presenter: NO

Using Hysteresis Loops to Examine Phosphorous Mobilization in southern Ontario Tile Drains

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Nutrient loading from agricultural landscapes can result in frequent algal blooms in surface water bodies. Agricultural tile drains are a known source of phosphorus (P) that can contribute to eutrophication. However, the hydrological and biogeochemical mechanics that drive the timing, mobilization and magnitude of P-export from tile drains are not as well known. Hysteresis loops between discharge and P can be used to better understand the mobilization and transport pathways of phosphorus in tile drained systems. Continuous discharge and high-frequency instantaneous P concentrations were examined for sixty events for two tile drains of differing slope position in a sandy loam agricultural field in southern Ontario over the course of a 28-month period between 2011 and 2013. Hysteresis patterns in the events were assigned to one of seven "hysteresis categories" providing insight into P-supply limitation (clockwise loop), delayed P-mobilization (counter-clockwise loop) or different combinations of these loops in the soils above the tile drains. Results indicate that the majority of dissolved and particulate P loads were lost in clockwise loop (supply limited) events, even though less than half the events were clockwise loops by count. This suggesting that the bulk of P-loss occurs during a limited number of very large events that resulted in phosphorus exhaustion in the runoff. The distribution of hysteresis loops differed between up- and downslope positions, indicating the influence of lateral flow to the tile in the lower slope position. Generally, the spring and fall exhibited more complex (multiple and/or multi-directional) hysteresis loops, likely due to higher soil moisture conditions and the greater likelihood of successive events. Implications for P-loading and speciation will be discussed.

Preferred Platform: Oral Presentation

Student Presenter: N

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

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Phosphorus (P) inputs to human-impacted watersheds have more than doubled over the last century in response to the use of fertilizers, detergents, and P additives in a range of products, from animal feed to motor oil. Although mass balance studies consistently show P inputs exceeding outputs in human-impacted areas, 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 Grand River Watershed, we have not only reconstructed total phosphorus yields at the watershed outlet, but also 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, even after significant improvements in nutrient management practices, such estimates of legacy P accumulation will be crucial to setting realistic targets for reducing P loading and for better understanding the contribution of P legacies to current and future lake nutrient dynamics.

Preferred Platform: Oral Presentation

Student Presenter: N

RZ-TRADEOFF: A New Model to Estimate Riparian Water and Air Quality Functions

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Riparian zones are often used as best management practices due to their ability to remove nitrate (NO₃⁻) from subsurface flow. In this context, research suggests that beyond local biogeochemical controls, the impact of riparian zones on nitrogen removal, as well as other functions such as phosphorus dynamics and greenhouse gas emissions, largely depends on land use/land cover, hydrogeomorphology, and climate. Here, we present RZ-TRADEOFF, a novel and scalable stochastic model that connects multiple riparian functions (NO₃⁻ and phosphate [PO₄³⁻] concentration and removal in subsurface flow, total phosphorus [TP] removal in overland flow, nitrous oxide [N₂O], methane [CH₄], and carbon dioxide [CO₂] emissions, water table) to landscape hydrogeomorphic characteristics, climate/weather, and land cover/land use. RZ-TRADEOFF was developed with data from past studies and digital databases (e.g. NRCS [Natural Resources Conservation Service] Web Soil Survey), and validated with additional independent data collected from the literature. Three functions (water table, PO₄³⁻ and CO₂) were observed to be significantly influenced by climate/weather, while the others were primarily influenced by hydrogeomorphology and land use. From a management standpoint, RZ-TRADEOFF significantly advances our ability to predict multiple water and air quality riparian functions using easily accessible data over large areas of the landscape due to its scalability.

Preferred Platform: Oral Presentation

Student Presenter: no

A stochastic modelling framework for processes in the soil-plant-atmosphere continuum at landscape scale

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The fate and behavior of agrochemicals on the landscape scale is often only vaguely known. Reasons for this relate to the fact that lab results are usually not sufficiently informative for modelling transport and transformation processes in natural, heterogeneous systems, the relevant properties of which are typically not well known. Against this background, a newly established large collaborative research center (SFB 1253 CAMPOS) will conduct integrated research on the environmental fate of agrochemicals in all of the water compartments of a mesoscale catchment, located in south-western Germany. A central aim is to inform numerical models describing the governing processes and system properties by setting up a stochastic modelling framework. Since the processes in the soil-crop-atmosphere continuum are a key control for water and matter fluxes beyond the rooting zone, spatially and temporally explicit coupled process models are used. However, the quantification of fluxes on the landscape scale with numerical models is inherently uncertain. Our 2D Monte Carlo double-looping approach integrates spatially variable but explicit soil columns in which information on soil type and agricultural management at the landscape scale is contained, including stochastic soil-plant model parameters and input variables. As a first building block of the stochastic engine, information on soil properties contained in soil maps and from soil core observations were used to describe the spatial variability of soil properties. The results of these soil-crop model simulations provide statistical distributions of water and solute fluxes at rooting depth. In our presentation, we address questions regarding the necessary spatial resolution of soil properties for different management units of the catchment, and compare the simulated against the measured concentrations of nitrates in the various water compartments.

Preferred Platform: Oral Presentation

Student Presenter: No

Quantifying aquatic carbon and nitrogen dynamics and greenhouse gas mitigation potential in riparian agroforestry systems

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Riparian areas can be defined as vegetation strips bordering a water body. Riparian zones can be designed to provide multifunctional ecosystem services including: C sequestration to help mitigate climate change and improving water quality by reducing C and N inputs into the water body. These two services of riparian zones guide my research. While, there is a lot of information regarding the adverse effects of the nutrient runoff on water quality, information on greenhouse gas (GHG) emissions from the aquatic component of the riparian zones is limited. The objective of this study is to quantify the GHG emission potential of riparian zones; and to quantify the carbon (C) and nitrogen (N) dynamics in the aquatic component of the Riparian Agroforestry Systems (RAFS). Agroforestry is a natural resource management system that is defined by the presence of trees on a farmland. RAFS therefore refer to the tree plantations along the streams, adjacent to the farmlands. Three different RAFS, located along the same stream, are being monitored: 1) a undisturbed natural forest (UNF) riparian area, unaltered for over 150 years; 2) a rehabilitated forest (RH) riparian area, restored over 25 years ago; and 3) a grassland (GRS) riparian area. The study sites are located along Washington Creek in Oxford County, in Ontario. Water samples are analyzed for GHG (including CO₂, CH₄, and N₂O), DOC, TN, NH₄⁺, NO₃⁻, and dissolved organic N (DON). The data collected for both the summer, 2017 and fall, 2017 sampling seasons has shown that both the aquatic CO₂ & N₂O emissions were highest at the UNF site and lowest at the GRS site. However, the CH₄ emissions were highest at the GRS site and lowest at the UNF site.

Preferred Platform: Oral Presentation

Student Presenter: Y

The influence of soil characteristics and season on dissolved reactive phosphorus and nitrate uptake with runoff through riparian buffers in Manitoba

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On the Canadian Prairies a high proportion of runoff and nutrient export occurs with snowmelt and most nutrient transport occurs in a dissolved form. Measurement of the retention of dissolved nutrients in riparian areas with snowmelt runoff are much less common than for rainfall runoff, but a range of responses including both uptake and release have been observed in those studies that have been completed. Where low rates of uptake or release have been observed this is generally attributed to frozen soils, lower biotic uptake, and release of nutrients from senesced vegetation. In the research presented here we evaluate whether the potential for uptake of dissolved reactive phosphorus (DRP) and NO₃⁻ differ significantly between snowmelt and summer seasons with flow through riparian buffers surrounded by cropland in Manitoba. The majority of flow in this landscape occurs through small channels of preferential surface flow, so pulsed releases of a conservative tracer and dissolved nutrients were utilized to measure uptake rates at 19 riparian sites. Both uptake and release were observed across sites so it was not possible to calculate nutrient spiraling metrics as originally planned. Mass retention of DRP and NO₃⁻ were calculated as a percentage of tracer input. Although mean uptake rates observed for both nutrients in summer were higher than for snowmelt, these differences were not statistically significant and responses varied widely. Uptake of NO₃⁻ was observed more frequently in both seasons than for DRP. Aerial uptake rate of DRP showed a significant negative relationship ($p=0.001$) with soil P and a P saturation index across both seasons. Overall, there appears to be potential to manage riparian areas in the region to retain NO₃⁻, but release of DRP will remain a challenge without removal by harvesting vegetation and/or reduction of export from upstream sources.

Preferred Platform: Oral Presentation

Student Presenter: N

1997-2017: Twenty years of riparian zone research: where to next?

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Riparian zones have been used for water quality management with respect to nitrate (NO_3^-) in subsurface flow and total phosphorus (TP), sediments, and pesticides in overland flow for decades. Only recently has the dynamics of soluble reactive phosphorus (SRP), mercury (Hg), emerging contaminants, and greenhouse gas fluxes (GHG: N_2O , CO_2 , CH_4) been examined in riparian zones. For this talk, we show that riparian zones are overall efficient at reducing emerging contaminants in subsurface flow and only function as hot spots of methylmercury production in the landscape when dominated by Hg rich wet organic soils. However, riparian zones do not provide consistent benefits with respect to SRP removal or GHG emissions. More research should be conducted on how various practices, including stream restoration, subsurface drainage, two-stage ditches, beaver dam analogues, denitrification bioreactors and permeable reactive barriers, artificial wetlands, or short rotation forestry crops impact riparian water and air quality functions. Riparian zone benefits should also be discussed not only with respect to water and air quality, but also with respect to water quality or air quality tradeoffs associated with riparian zone management in a multi-contaminants / multi-use landscape context.

Preferred Platform: Oral Presentation

Student Presenter: No

Quantifying Phosphorus Mobilization from a Riparian Wetland Impacted by Bunker Silo Effluent in Ontario, Canada

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Agricultural phosphorus (P) is a large contributor to the eutrophication of freshwater ecosystems. Runoff from livestock farming can contribute substantial loads of P to surface and groundwater; consequently, many farmers employ riparian wetlands to reduce P loads. However, the chronic leaching of effluent can build up high legacy stores of P over time, that can exceed the capacity of the riparian wetland to store P and the wetland can subsequently shift to a P source. Bunker silo effluent is a particularly challenging P source, with acidic, highly elevated nutrient concentrations. This study characterizes nutrient dynamics in a riparian wetland and stream adjacent to a dairy farm in Ontario, Canada. The objectives of the study are to 1) quantify P loads to streamflow from the bunker silo effluent and farmyard; and 2) to determine if the riparian wetland between the bunker silo and the stream is acting as a source of legacy P to the stream. High-frequency water samples were collected upstream and downstream of the farm under a range of flow conditions. A series of nested piezometers were installed across the riparian zone at depths of 25, 50, and 75 cm, with wells installed to a depth of 75 cm. Results demonstrate that there are significant increases in P concentrations downstream of the farmyard and bunker silos, and these are most apparent under elevated flow conditions. Although 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, indicating that the wetland is acting as a P source to the stream. These findings provide an insight into the significance of critical source areas, and the importance of point sources in the landscape that contribute substantial P loads to freshwater ecosystems.

Preferred Platform: Poster Presentation

Student Presenter: Y

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

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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.

Preferred Platform: Poster Presentation

Student Presenter: Y

Event-Based Analysis of Water Chemistry to Infer Runoff and Phosphorus Sources to a Prairie Stream

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While runoff and nutrient sources contributing to a stream are difficult to measure directly, they can be inferred by examining the temporal variation of electrical conductivity (EC) – as a tracer of runoff origin – and that of soluble reactive phosphorus (SRP) – as an indicator of dissolved nutrient species transported in runoff. The relation between EC, SRP and stream discharge is also key to understanding the timing of runoff and nutrient mobilization during rainfall events. Hence, to infer water and phosphorus sources to a Prairie stream, focus was the Broughton's Creek located in the Canadian portion of the Prairie pothole region (Manitoba, Canada). A capacitance water level logger was deployed in a stilling well (i.e., above ground well) to monitor creek stage every 15 minutes. Creek water samples were collected with an autosampler every two days during the 2013 and 2014 open water seasons (May to October) and tested for EC and SRP concentrations. Over the two years, 10 rainfall events were identified, and 10+ creek response metrics (hydrologic and chemical) were calculated for each event. Spearman's rank correlation coefficients between creek response metrics and rainfall magnitude and intensity were estimated to understand climatic controls on the mobilization of water and phosphorus to the creek. Scatter plots of creek stage versus SRP or EC values were also built to assess concentration-discharge relationships and hysteresis patterns and thus infer runoff and phosphorus sources. Initial data analysis reveals stronger correlations between climatic indicators and hydrologic response metrics, as opposed to chemical response metrics. Temporal shifts were also identified in the hysteresis patterns, suggesting that a wide variety of sources and mechanisms are involved in the supply of water and phosphorus to the creek. Future analyses will examine whether climatic indicators can be used as predictors of active runoff and phosphorus sources.

Preferred Platform: Poster Presentation

Student Presenter: Y

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

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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 greater sensitivity to air temperatures with deeper frost, and largely had drier surface soil moisture conditions. Preliminary results reveal that soil experienced net P mineralization when under snow cover, but net P immobilization where snow cover was absent. Soil water-extractable P pools and net P mineralization rates throughout the winter and spring will be presented and related to environmental 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.

Preferred Platform: Poster Presentation

Student Presenter: Y

Monitoring subsurface microbial processes using non-invasive geophysical methods

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Non-invasive geophysical methods, such as spectral induced polarization (SIP), are sensitive to subsurface microbial processes and offer a comparatively inexpensive alternative to accessing the subsurface, providing in situ information at high spatial and temporal resolutions. The key challenge in using SIP to monitor soil biogeochemistry, is to establish baselines for measured geophysical signatures to create relationships between relevant reactive processes and measured responses. We conducted bench-scale experiments in columns packed with iron-oxide coated and quartz sand, inoculated with *Shewanella oneidensis* supplemented with a carbon source (lactate) and electron acceptor (nitrate) and monitored microbial dynamics with SIP. Complementary biogeochemical measurements and peak polarization responses were fitted to a reactive transport model. Our results highlight that measured peaks in polarization relate to microbial growth and decay dynamics, even at relatively low cell densities (10^8 cells mL⁻¹) and are directly dependent on electron acceptor availability. Further modeling analysis of SIP frequency peaks (Cole-Cole relaxation) shows that polarization length-scales, controlling the SIP response, are on the order of 1-3 μ m, 2 orders of magnitude smaller than the sand grains, suggesting that the cells themselves are the dominant control on observed electrical signal dynamics. The coupled geophysical-biogeochemical modeling analysis provides encouraging evidence for the application of SIP for in situ non-destructive monitoring of microbial dynamics. SIP can be applied to more complex systems to advance our integrated understanding of how microbially mediated processes, that play a critical role in controlling regional biogeochemical cycles, respond to dynamic environmental change.

Preferred Platform: Poster Presentation

Student Presenter: Y

Investigating conditions of the rhizosphere in a suburban river in response to WWTP effluent unloading

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In this study we are interested in the responses of macrophytes's rhizosphere with the concentration of nutrients from WWTP effluent loading in a lotic ecosystem located at a lowland suburban river in Berlin, Germany. Unloading of treated wastewater into a stream is known to increase the biomasses of macrophytes in a lotic system (Gücker et al., 2005). A sampling program of surface water with rhizospheric pore water of native macrophytes were performed in a suburban river affected by intermittent WWTP effluent loading. The location of the sampling was categorised to upstream and downstream reaches of a WWTP during the sampling campaigns. Two prominently present macrophytes, *Potamogeton pectinatus* and *Sparganium emersum*, were distributed along the river stretch. Samples were taken in rhizospheric pore waters of these species, coupled with surface water and macrophyte-free pore water. The samples are analysed for nutrient, alkalinity, salinity and pharmaceutical compounds. No increase of nitrate concentration, a commonly observed effect from a WWTP effluent discharge, were noted in habitats permeated with macrophytes. Although both *Potamogeton* sp and *Sparganium* sp indicate similar nutrient concentrations throughout the upstream and downstream reaches, the latter reported higher concentration of sulfate and ammonium after the effluent loading point, indicating a better potential of nutrient retention for *Sparganium* sp. This present study coupled with results of an ongoing pharmaceutical analysis could indicate the responses of how different macrophyte species could create conditions better nutrient cycling.

Preferred Platform: Poster Presentation

Student Presenter: Y

Soil hydrogeochemical processes under changing winter conditions

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Climate warming in Canada's cold regions is expected to significantly increase the vulnerability of these regions to changes in quantity and quality of surface water and groundwater. Temperature increases due to climate change are expected to alter the timing and duration of snow-cover in Canada's cold regions, which will expose soils to colder temperatures and increase the frequency of freeze-thaw events, all of which will affect soil biogeochemical processes. A mechanistic understanding of how freezing and thawing influence soil respiration, greenhouse gas emissions and leaching of nutrients to groundwater is necessary to predict how soil and water resources will respond to climate change. In this presentation, we present a novel approach, which combines the acquisition of integrated physical and chemical data in a newly-developed soil column system in which simulates realistic soil temperature profiles during freeze-thaw cycles. The results indicate that the time-dependent carbon (C) and nutrient dynamics are influenced by a combination of two key factors. Firstly, changes in temperature and oxygen availability affect soil geochemical activities. Secondly, the recurrent development of a physical ice barrier prevents exchange of C and nutrients between the soil and atmosphere during freezing conditions; removal of this barrier during thaw conditions increases the rates of C and nutrients leaching and production. During freezing, oxygen levels in the unsaturated zone decreased due to restricted gas exchange with the atmosphere. As the soil thawed, oxygen penetrated deeper into the soil enhancing the aerobic mineralization of organic C and other nutrients. The results from this study will help the interpretation of spring snowmelt pulses of dissolved C and nutrients in cold regions and the cumulative effects of winter soil geochemical processing on belowground pools of nutrients during the non-growing season.

Preferred Platform: Poster Presentation

Student Presenter: N

CGU_H_10: Recent Advances and Outstanding Challenges in Large-scale Watershed Modelling and Analysis

Conveners: Amin Haghnegahdar^{1*}, Jefferson Wong², Saman Razavi³, Yonas Dibike⁴

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Integration of GRACE data into a hydrology land-surface model in a snow dominated Canadian basin

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Snow is a very dynamic feature, which displays important spatial and temporal variabilities, depending on landscape, topography, forest cover and geographical location. Its measurement is challenging. Among satellite measurement techniques, gravimetric retrievals from the Gravity Recovery and Climate Experiment (GRACE) satellites provide useful information in capturing snow mass changes during snow accumulation and ablation seasons, at very large scales. A correlation analysis between GRACE-derived terrestrial water storage anomaly and multisource snow water equivalent anomaly data highlighted the important role of snow water equivalent (SWE) on terrestrial water storage (TWS) changes during winter. In the Liard basin, located in the Canadian land mass, it was found that SWE explains more than 60% of TWS variabilities. Hydrological modeling outputs are influenced by different uncertainties, such as model calibration and parameter optimization, meteorological forcing data, or model structure. The presence of these uncertainties motivates the need to combine existing observations with model to obtain improved estimations. In this study, GRACE observations were integrated into a hydrology land-surface model called MESH (Modélisation Environnementale Communautaire-Surface et Hydrologie). In order to improve the SWE estimations, ensemble Kalman smoother method was used to assimilate GRACE-derived TWS data into MESH model. The performance of the data assimilation method was evaluated against existing snow mass products over the Liard Basin.

Preferred Platform: Oral Presentation

Student Presenter: y

Application of MESH Land Surface-Hydrology Model to a Large River Basin in Iran

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In this work, we aim to enhance simulation of streamflows in Sefidrud River Basin in Iran, using advanced distributed coupled land surface-hydrology modelling system that allows for considering both water and energy balance, simultaneously. For this purpose, we apply Modélisation Environnementale– Surface et Hydrologie (MESH), which is a community platform for joint modeling of atmospheric, land surface and hydrologic models. In this MESH application, the Canadian land surface scheme (CLASS) is combined with WATROUTE hydrological routing component. Sefidrud river basin is the second largest river of the country and inflows to the Caspian Sea. The basin is nearly 65000 km² that is discretized into 683 grids (~10 km x 10 km). Most part of the basin is semiarid area with rangeland. 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. Preliminary results show that model gives reasonable water balance components for the basin. Simulated hydrographs are expected to improve significantly after incorporating three significant reservoirs located in this basin. This work is the first application of the MESH model in Iran, and is expected to significantly improve simulation and prediction of not only streamflows, but also other important water and energy fluxes such as soil moisture profile. Future works can include using MESH for climate and land use change impact studies in this basin.

Preferred Platform: Oral Presentation

Student Presenter: N

Stream temperature modeling of the Fraser river

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Increasing stream temperature trends have been observed in the Fraser in the past decades and climate change is very likely to result in further increases in the future, leading to potentially adverse consequences for aquatic ecosystems health and drinking water availability. To explore mechanisms responsible for the past and future trends, such as potential decadal variability, stream temperature is modeled with a one-dimensional stream temperature model, RBM, which has been integrated with the 1 Variable Infiltration Capacity (VIC) hydrology model. In RBM, the modeling of headwater inflow temperature is done using a statistical relation between air and stream temperature. However, this approach is only feasible with a relatively large set of observations for the calibration, which is not available on the Fraser basin. Further, it must also be assumed that the statistical relation remains valid when the water temperature model is applied in a climate change context. These two issues are addressed by taking advantage of the physically-based approach of VIC and the grid-based approach of RBM to model the headwater inflow temperature explicitly based on simulated soil temperature, air temperature and snow and glacier-melt contribution. Stream temperature series are reconstructed on the last decades using an upgraded version of VIC, which includes glacier process, and our upgraded version of RBM. The seasonal cycle and the inter-annual variability are first assessed against the available observations to evaluate RBM. Then, particular attention will be paid to past trends and the decadal variability of stream temperatures and associated mechanisms such as the role of glaciers in controlling temperature variability.

Preferred Platform: Oral Presentation

Student Presenter: N

Does land cover change offset or reinforce impacts of climate change on the hydrology of the Mackenzie River Basin?

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The Mackenzie River basin (MRB) is the largest in Canada covering an area of about 1.8 million square kilometers. It discharges about 300 cubic kilometers of water annually into the Arctic Ocean on average which represents the fifth largest discharge source into the Arctic globally. As such, it has a tremendous influence on ocean circulation through its large freshwater input. The basin itself has a highly variable climate due to its large altitude range (from sea level at the north outlet to over 4000 m in the western cordillera headwaters) as well as its large latitudinal range (52-70 degrees N). The hydrology of this basin is exceedingly complex in terms of runoff generation and movement to and through rivers due to the existence of large lakes, wetlands, and permafrost underlying more than half of the basin area. Observations indicate high rates of warming and associated land cover changes (e.g. shrubification) at high latitudes and Earth System Models (ESMs) project that these trends will continue, accompanied with enhanced precipitation. 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 at 0.125° spatial resolution. 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. Preliminary results show strong spatial heterogeneity of response, but overall increases in river flows, especially during the spring freshet which is also expected to start earlier, and reduced permafrost coverage, by 2100. Vegetation changes may partly offset the impacts of climate change in some areas.

Preferred Platform: Oral Presentation

Student Presenter: N

Modelling Alberta's Water Future: Challenges from Input Data to Hydrology and Climate Change

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The security of freshwater supplies is a growing concern worldwide. Process based hydrological models have been widely applied to study spatial and temporal dynamics of water supply and demand in large watersheds. The reliability of these predictions depends on various factors that are mainly related to input data, hydrological models, and climate change projections. We have developed agro-hydrological models of Alberta to study factors driving uncertainty in water resource projections. Alberta, a western province of Canada, is a case study that encompasses many of the water security challenges faced worldwide including natural complexity and human impacts. We used the Soil and Water Assessment Tool (SWAT) to simulate water budget, crop yields, and crop water consumption at 2255 subbasins at monthly time step in Alberta. The models were calibrated using the Sequential Uncertainty Fitting (SUFI2) program, based on the monthly river discharge data from 130 hydrometric stations, and crop yields of 67 and 11 counties under rainfed and irrigated conditions, respectively. Calibration of large distributed models is often subjective when a vast number of adjustable physical-parameters are allowed to vary within a broad range of values, since a seemingly good simulation can be obtained with erroneous parameter values. We have developed a novel framework for inclusion or exclusion of datasets to avoid over-calibration of multi-gauge, multi-variable, and multi-parameter models, providing uncertainty analysis. Projection of hydrologic variables, using the output from various Global Climate Models under extreme RCP trajectories, showed larger uncertainty in southern part of the province where internal climate variability dominates the effects of external forcing (e.g. global warming due to anthropogenic factors). Our future direction is to improve projection of “regional” hydrological models under global climate change scenarios and natural climate variability. Our overall goal is to develop reliable models with the end result being improved water management and improved policy responses to challenges in water security that are faced worldwide.

Preferred Platform: Oral Presentation

Student Presenter: N

An improved representation of surface heterogeneity in the Variable Infiltration Capacity (VIC) model using Grouped Response Units (GRU)

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The increase in water demands such as irrigation, glacier retreat, changing land cover and permafrost thaw are among many changes Canadian basins are facing. For pan-Canadian modelling of water futures, a large-scale, integrated modeling approach with sufficient process representation is required to account for the aforementioned changes. Large-scale models often aggregate the spatial heterogeneity of available data at a larger scale.

We use the Variable Infiltration Capacity (VIC) model (version 5). Conventionally, the model has been set up on regular grids, for example of 0.5° or 1.0° degree. In this conventional setting, each grid can have only a single configuration of soil type and soil layers, but accommodate different land covers (vegetation types). The output of each grid is an aggregation of all the fluxes from the various sub-grid elements (land covers). In this study, however, we develop a computationally efficient VIC model configuration that explicitly accommodates all the information on soil, vegetation, elevation and forcing data. Unlike the common setup, we run VIC for Group Response Units (GRUs) which have similar land cover, soil type, elevation and forcing data. These GRUs are not necessarily based on regular grids. The advantages of this new configuration include:

- More accurate spatial resolution for setting up a model based on the heterogeneity of available data, while avoiding any unnecessary computational burden.
- The effect of each land cover, soil type and elevation zone can be separately controlled.
- Different sources of information can be included in setting up non-regular units to better represent the physics. As an example, non-regular units can be modified based on hillslope aspects to overcome the “flat Earth concept” of the VIC model.
- Effective regularization of parameters are easier to implement with the new model set up.

We present results of model performance under current and future climates from a first case study, in which the VIC-GRU model is set up for 23 nested basins of the South Saskatchewan River.

Preferred Platform: Oral Presentation

Student Presenter: N

Developing a Pan-Canadian Hydrologic Routing Network of Lakes and Rivers

Ming Han, Juliane Mai, James R. Craig, Bryan A. Tolson, Etienne Gaborit, Konhee Lee, Hongli Liu

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Lakes and reservoirs have critical impact on hydrological, biogeochemical, and ecological process, and they should be one of the essential components in our hydrological and eco-hydrological models. However, limited research has explicitly included lakes in the hydrologic routing of streamflow through a drainage network. Lakes can greatly reduce flows and delay streamflow delivery downstream and the impacts of ignoring lakes of different sizes still requires more research. In this study, lake and river characteristics, as well as detailed sub-basin delineation products, were compiled from the HydroLAKES database and the HydroSHEDS database and were subsequently used to develop a hydrologic routing network including both lakes and river channels for all of Canada. All lakes in the database (including those as small as 10 ha) were explicitly included in the developed routing network provided and were directly connected to the HydroSHEDS drainage network. The routing network was constructed in the format of the Raven hydrologic modelling framework software which has a variety of different process models for routing implemented. As a case study, a subregion of the Hudson Bay drainage basin (61621 km²) was utilized to route 8 years of GEM-HYDRO land surface model simulated flows. In this model 2200 lakes were explicitly represented in Raven. The HydroLAKES database supplied lake volume, average depth, pour point elevations and lake areas. Further processing of the HydroSHEDS DEM generated an alternative to a vertical side-slope assumption for the stage-volume relationship for each lake. Results will be presented comparing routing results based on a gridded model (at the resolution of GEM-HYDRO) and a subbasin model (derived from HydroSHEDS subbasins). Compared to the current routing tool for GEM-HYDRO outputs, initial results show substantial improvements in runtime. The impact on streamflow of small lakes (< 40 km²) compared to larger lakes (> 40 km²) is also studied along with an assessment of simulated streamflow sensitivity to the assumption of vertical side slopes for all lakes.

Preferred Platform: Oral Presentation

Student Presenter: Y

Assessing Watershed Model Parameterization with Stable Water Isotope Data

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Precise and accurate prediction of streamflow under changing climatic conditions, or in ungauged or recently gauged locations, requires hydrologic models capable of accurately representing the processes generating streamflow. Often, however, data for individual processes and storages are even less common than meteorologic or hydrometric data in mid-to-high latitude regions, and is more costly and less feasible to obtain. Data scarcity can result in large amounts of uncertainty in model calibration and simulation output. Stable water isotopes have proven to be useful diagnostic variables for hydrological modelling, with some uncertainty as to the degree of usefulness for parameter constraint and both deuterium and oxygen-18 simulations are embedded within the continuous, semi-distributed hydrologic model isoWATFLOOD. In preparation for applying SWI tracers in the entire Mackenzie basin, the isoWATFLOOD model has been applied to the Athabasca basin in northern Alberta in an isotope-enabled model calibration exercise. The fluxes in the hydrologic model are evaluated by comparing SWI tracer model results to observed data, particularly for evaporation and snow melt water fluxes. The potential utility of supplementing hydrometric data with intermittent SWI data in calibration is also assessed.

Preferred Platform: Oral Presentation

Student Presenter: Y

Efficient treatment of climate data uncertainty in ensemble Kalman filter based on an existing historical climate ensemble dataset

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Successful data assimilation relies on the accurate estimation of forcing data uncertainty. The estimation of the forcing data uncertainty requires the specification of the hyper-parameters of statistical error models. In practice, modelers use trial-and-error tuning processes to determine hyper-parameter values, which takes intensive time and computational cost. To improve the efficiency of climate data uncertainty estimation of the ensemble Kalman filter, this work demonstrates the direct utilization of an existing ensemble climate product to represent climate data uncertainty. Specifically, the Newman et al. (2015) dataset, covering the continental US, was used to represent precipitation and temperature uncertainties in this study. This is the first study to compare the Newman et al. (2015) dataset with the carefully tuned hyper-parameters generated climate ensemble, called traditional ensemble, in terms of ensemble flow forecasting. The comparison results of 20 Quebec catchments show that the Newman et al. (2015) ensemble yields better, at least practically the same deterministic and ensemble flow forecasts than the traditional ensemble. However, the analyst and experimental time required to use the Newman et al. (2015) dataset is much less compared to the fastidious hyper-parameter tuning.

Preferred Platform: Oral Presentation

Student Presenter: Y

Five Reasons Why You Should Know the Canadian Surface Prediction Archive CaSPAr

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

Preferred Platform: Oral Presentation

Student Presenter: N

CGU_H_10

WATROF 2

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In the early 1990s, atmospheric modellers discovered the importance of soil moisture, which initiated the era of coupled atmospheric /hydrological modelling. Physically-based gridded models, such as MESH, were developed using a control volume approach to evaluate water and energy balances. Detailed land surface schemes evolved to meet the needs of these gridded watershed models, while detailed land cover mapping, satellite imagery, and digital terrain models provided tantalizing opportunities to model watersheds in detail. Modelling soil moisture movement has proven to be problematic. Although vertical processes can be described by well-established classical techniques, no consensus on how to address lateral flow has been reached. Many models have adopted a set of characteristic curves that estimate outflow from the various storages. However, given the diversity of topography, terrain, and temperature conditions of watersheds, a general algorithm to address lateral flow is yet to be developed. WATROF is a MESH subroutine that includes algorithms to close the water balance on an ad hoc basis. Many variations on these algorithms have been tested. With recent experiences and insights, WATROF2 attempts to encompass the current consensus on addressing lateral flow in a variety of watersheds. Embedded within MESH, WATROF2 is ready to receive specialty models developed for specific watershed types. This paper will describe the elements of WATROF2 and compare and contrast its performance with WATROF.

Preferred Platform: Oral Presentation

Student Presenter: No

Robust Multi-Objective Calibration of a Semi-Distributed Hydrological Model

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Calibration techniques were investigated on how to best optimize a 149 parameter, semi-distributed hydrological model of the Lake of the Woods – Rainy Lake (LOWRL) watershed, a model that is primarily used for forecasting purposes. Single objective optimization formulations based on streamflow or reservoir inflows solved using the Dynamically Dimensioned Search (DDS) algorithm were compared with multiobjective optimization formulations using the Parallel Pareto Archived DDS (ParaPADDs). Results from calibration tests against known parameter and solution sets showed that ParaPADDs was able to find a solution with streamflow and reservoir Nash-Sutcliffe coefficients of 0.99 using 8000 simulations, demonstrating the effectiveness of the multiobjective algorithm. When the LOWRL model was calibrated to observations, the optimal solutions resulted in streamflow and reservoir inflow Nash-Sutcliffe coefficients of 0.75 and 0.87, respectively. The optimal number of simulations for the calibration of the 149 parameter model was found to be 4000, with higher numbers of simulations resulting in only marginal improvements. Parameter ranges were varied by an order of magnitude but were found to not have a significant effect on optimization results. The diversity of parameter sets obtained from ParaPADDs solutions were investigated and found to be related to the diversity of the resulting streamflow and reservoir Nash-Sutcliffe coefficients. Results highlight the ability of ParaPADDs to handle a high dimensional calibration problem and demonstrate the value of solving a multi-objective rather than a single objective model calibration formulation.

Preferred Platform: Oral Presentation

Student Presenter: N

Diagnosing alteration in natural streamflow regime: A new look at an old problem

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Climate variability and change have significant impacts on natural streamflow. Understanding regime changes in natural streamflow is important for diagnosing the effects of climate change and for promoting sustainable water resource management under changing conditions. Typically, conventional approaches to assess the alteration in natural flow regime consider one or more streamflow characteristics and apply one or more statistical tests to extract the form and magnitude of change in individual flow characteristics. Here we propose an alternative approach to diagnose the change in natural streamflow regime by characterizing the gradual shift in shape and variability around the long-term annual streamflow hydrographs, which inherently include multiple streamflow characteristics within. The approach is based on (1) considering a wide range of streamflow features that describe the characteristics of long-term annual hydrographs and modes of natural variability therein; (2) clustering streamflow series based on these features into a set of physically-relevant streamflow classes; and (3) monitoring how streamflow series gradually depart from one streamflow class and move toward others using a systematic approach. To test this framework, we consider the streamflow data from 106 Canadian gauges during the period of 1966 to 2010. Fuzzy clustering is used to classify the streamflow series during a common period, in which all streamflow series are associated to all clusters with certain degrees of belongingness. At each streamflow gauge, we then measure the gradual departure in the degrees of belongingness using a moving window and take this information as an indicator for regime shift in natural streamflow. Based on this methodology, we diagnose some significant changes in shape and variability of streamflow regime that confirm the findings of previous studies, yet provide more holistic understanding on recent changes in natural streamflow regime throughout the country.

Preferred Platform: Oral Presentation

Student Presenter: Y

Progress towards Building Assiniboine Watershed Model for Hydrological and Nutrient Transport Simulation

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The water quality of Lake Winnipeg has deteriorated in the last few decades due to multiple sources of excessive nutrients (phosphorus and nitrogen) that have increased the frequency and magnitude of algal bloom. This work is part of the Lake Winnipeg Basin Initiative (LWBI) modeling effort towards developing predictive capabilities in support of nutrient management in Lake Winnipeg and its basins. This poster will present the progress being made in setting up a hydrologic and nutrient transport model for the Assiniboine watershed, one of the Lake Winnipeg sub-basins, using the Soil and Water Assessment Tool (SWAT) modelling platform. The model is setup using publically available digital elevation map (DEM), land use and soil data as well as gridded climate data for the historical period. Hydrologic model calibration and validation is underway using the SWAT-CUP/SUFI-2 framework based on observed streamflow data at a number of stations throughout the watershed. The well calibrated and validated model will eventually be applied to assess the effects of land use change, wetland drainage, and other management scenarios on nutrient export to Lake Winnipeg. The potential impacts of climate variability and change on the snow and hydrologic regime of the watershed will also be examined using statistically downscaled CMIP5 climate scenarios.

Preferred Platform: Poster Presentation

Student Presenter: N

Adapting to changing water in Alberta: assessment of future water endowments to study regional water, food, energy, and environment dynamics

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Canada's economy relies on industries that depend on adequate supplies of freshwater. Water contributes up to \$200 billion annually to the Canadian economy from petroleum and agricultural production alone that may be jeopardized by variable water resources due to climate change. Therefore, accurate projections of the impacts of climate change is necessary for adaptive planning.

Application of distributed, physical, and process-based eco-hydro(geo)logical models is among the best available means to examine challenges in water security in the face of uncertain climate change. Despite advances in smaller scale modelling, the dynamic simulation of water supply is limited in large, complex watersheds due to inadequate representation of key hydrologic features in wet, dry, and cold hydrologic conditions. Furthermore, uncertainties exist in these projections due to poor integration of both short-term high frequency (e.g. El Niño/ENSO) and long-term lower frequency (e.g. Pacific Decadal Oscillations-PDO) climatic oscillations in the climate and hydrologic projections.

We have developed models to study water supply and demand components at a high spatial and temporal resolution by providing uncertainty prediction in Alberta. We have modelled blue and green water supply and demand in 2255 subbasins in Alberta. The modeled data are used to project water related risks and opportunities to various water use sectors including agriculture, petroleum, hydropower and municipalities in the province. Statistical approaches are developed to study the impacts of changes in hydrologic water pattern and conflict over water resources on wetland's viability in the province. The long-term goal is development of *regional* water predictive models that will consider cumulative effects of natural features (e.g., glaciers, snow, soil, vegetation, SW-GW interaction); anthropogenic factors (e.g., dams, irrigation, industrial development); and climate change and variability scenarios on water quantity and quality under different spatial and temporal scales. The end result will be tools that provide improved water management and policy responses to challenges in water security in the water-food-energy-environment nexus that will help formulate adaptive measures for sustainable economy in the future.

Preferred Platform: Poster Presentation

Student Presenter: N

Evaluating conceptual numerical models of Boreal Plains Hydrology

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Hydrology in the Boreal Plains eco-region of Canada is complicated for various reasons. For instance, in this region, Aspen trees have been observed to tap adjacent wetlands and transfer water to the uplands for future use. The flat landscape, with a large portion of wetlands, limits hydrologic connectivity, and is dominated by fill and spill cascades during large melt or rain events. There are also deep soil deposits in the region, which provide ample storage between years. This storage is important since, in an average year, actual evapotranspiration is higher than total precipitation. This also means, that in an average year, the change in storage in the basin is not equal to zero. Due to this complicated hydrology, standard modelling approaches have demonstrated a poor performance in the region at all scales; including the basin scale. This is problematic since basin scale hydrologic models are often used to inform policy decisions. The Raven hydrologic framework is used here to explore different hydrologic model configurations in this ecoregion with the goal of improving our ability to predict basin-scale hydrologic response in the Boreal Plains. By explicitly considering wetland to upland transfer, geographically isolated wetlands and riparian wetlands, and interannual storage changes, the models are used to explore the degree of complexity necessary to better represent Boreal Plains hydrology in a data-limited environment.

Preferred Platform: Poster Presentation

Student Presenter: Y

Addressing hydrologic modelling needs in the Canadian Shield

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The Canadian Shield occupies about one-third of Canada's land mass and contains much of Canada's freshwater resources. Two key hydrological characteristics of the Canadian Shield impose challenges for modelers. First, the soil structure of the Canadian Shield consists mostly of thin soil layer followed by a layer of impermeable bedrock. This soil structure limits the amount of water stored in soil storage, and is inconsistent with many standard rainfall-runoff model representations. Second, approximately 25% of the area contains open water, including small lake systems and wetlands. These small lake systems play a crucial role in the hydrology, but are often difficult to represent in a regional model as the stage-discharge relationships of natural lake systems are not readily available. Using the flexible Raven hydrological modelling framework, simple yet effective methods of representing lake systems have been implemented. Water runoff from the bedrock is routed to a representative lake with a weir-like outlet structure. The width of the lake was set to be a calibration parameter within a reasonable range based on GIS analysis. The Raven model was deployed in two basins in Ontario: The Kaministiquia Watershed and The Lake of the Woods Watershed. Model performance and inter-comparisons with existing models of the same systems is reported.

Preferred Platform: Poster Presentation

Student Presenter: Y

Upscaling spatially-variable groundwater discharge into streams using flowlength probability distributions

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Subsurface flow into streams during and after recharge events is a significant streamflow generation process that is difficult to properly include in two-dimensional (2D) semi-distributed watershed models. In these models, baseflow is typically treated as a calibration parameter which controls the bulk release of water from groundwater storage to streamflow without reference to known groundwater discharge relationships. Here, a novel upscaling methodology is implemented to scale known one-dimensional (1D) transient groundwater discharge relationships to an equivalent 2D watershed average based upon known groundwater system characterization. The methodology utilizes a probabilistic distribution of 1D flowlengths in the watershed derived only from elevation data. Heterogeneity in the watershed is captured in the description of each flowpath and the corresponding 1D groundwater solution, which accounts for varying geometry, terrain, conductivity, and recharge rates. The known distribution of flowlengths is translated into an equivalent distribution of subsurface flow in all flowpaths using the derived distribution method. The statistical average of the subsurface flow distribution provides a single, upscaled value of mean watershed subsurface flow contributed to streamflow. A case study of the Port Granby watershed in Southern Ontario is used to demonstrate the efficacy of this method. The results of this case study demonstrate the benefit of accounting for subsurface flow using this method, which requires no additional data beyond that required in a typical 2D watershed model.

Preferred Platform: Poster Presentation

Student Presenter: Y

Paying the PIED Piper: Visualization of large geochemical datasets using new approaches with Piper Diagrams

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Since the Piper Diagram was first developed in 1944, its projection of two ternary plots onto a common diamond field has increased in popularity and is now one of the most familiar and effective tools in the hydrogeologist's toolbox. Within the Piper Diagram, three individual points fully display the major ionic species of a water sample. Datasets have continued to grow in size and availability as additional field measurements and modeling results are shared more effectively in online databases. This growth presents opportunities and challenges for data analysis and communication—larger and longer datasets increase the ability to identify trends and patterns, but traditional Piper Diagrams are quickly overwhelmed in large datasets, as dense points overlap and become obscured. We present new code that can extend familiar biaxial plotting techniques to Piper Diagrams in novel applications to effectively display large datasets. This code, Plotting Interesting Environmental Data (PIED) Piper, exists as both a Matlab code and a stand-alone executable and is the first code written in the Matlab environment to generate Piper Diagrams. We present a variety of illustrative examples to demonstrate 1) how limitations in displays of large datasets may be overcome with translucent symbology, contours and colormaps to identify trends and patterns, 2) how clusters of similar points can be identified and differentiated with convex hulls, and 3) how temporal-and-spatial patterns may be visually diagnosed with image groups and movies. These techniques allow PIED Piper users to present large field and model datasets and achieve the two goals of visualization: data analysis and data communication.

Preferred Platform: Poster Presentation

Student Presenter: N

Exploring the Effect of a Changing Landscape on Water Storage in the Shullcas River Basin

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The Shullcas River Basin, located in the high-altitude Andes of Central Peru, is being impacted by rapid climate change and glacial recession. The literature indicates that the loss of glacier mass initially causes dry season stream discharge to increase, then decrease to a lower level. Many proglacial watersheds in Peru have already passed the point of peak water, after which dry season discharge begins to decline, posing a threat to water resources. The complex role of vegetation dynamics on watershed hydrology is not considered in peak water projections despite the potential for the combination of climate change and glacial recession to change the landscape. This study investigates changes in the landscape of the Shullcas River Basin in recent years and how these different land cover types store and release water. Four Hydrological response units (HRUs), representing four different ecosystems (pampa wetland, bofedale wetland, grassy hillslope and rock outcrop) were simulated in Hydrus-1D. Model inputs include the soil profile of each ecosystem, soil water storage properties of each horizon, an atmospheric upper-boundary condition, a deep-drainage lower boundary condition, and surface and lower boundary discharge. The Priestley-Taylor, Malmstrom, Hamon and Hargreaves methods for calculating evapotranspiration are compared. Changes in the distribution and occurrence of land cover types in the basin was assessed using remote sensing data. Four Landsat images of the watershed collected between 1985 and 2015 were classified by land cover type. Preliminary results show that land cover changes to the wetland and grassland areas are highly variable throughout the watershed. These preliminary results support the hypothesis that proglacial land cover change can significantly impact hydrology in a post peak-water setting.

Preferred Platform: Poster Presentation

Student Presenter: Y

A Comparison of VIC Hydrologic Simulation Using Different Precipitation Datasets in the Lake Erie Basin

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Precipitation is one of the most critical components in hydrologic modelling. For distributed hydrologic models, reliable gridded input precipitation datasets are required for an accurate analysis of catchment hydrologic response. Spatially distributed precipitation datasets, however, are always obtained using interpolation and assimilation techniques that could inevitably cause uncertainty in these reanalysis data because of the grid resolution, the density of observational stations, and the topography of the region. Two examples of such gridded precipitation datasets are employed for this study, i.e. the Canadian Precipitation Analysis (CaPA) and a recently developed reforecast product by Environment and Climate Change Canada – the Regional Deterministic Reforecast System (RDRS). This study evaluates the spatiotemporal characteristics of precipitation from the CaPA and the RDRS product over the Lake Erie Basin (LEB).¹ The differences between these two datasets were identified in terms of the basic statistical characteristics such as mean, standard deviation, quantiles, and the spatial variability. We then employed the macro-scale distributed hydrologic model variable infiltration capacity (VIC), which was driven by CaPA and RDRS precipitation, respectively, to simulate hydrologic processes in the LEB. Afterwards, the hydrologic responses of the LEB with respect to these precipitation products were comparatively analyzed. The hydrologic fluxes simulated by VIC, such as evapotranspiration, runoff and baseflow were evaluated for these two forcing schemes in terms of their spatial characteristics and temporal variations in different seasons. The results will shed light upon the impact of various precipitation datasets in hydrologic response studies in the Lake Erie Basin.

Preferred Platform: Poster Presentation

Student Presenter: Y

The hydrological impacts of shrub in semi-arid regions in Canadian Land Surface Scheme

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Shrub species prevail in water-stressed, saline, fire-perturbed or grazing-perturbed environments. Realistic incorporation of shrub species' biophysical and biochemical processes into climate models is the prerequisite for quantifying shrub expansion's influence in ecosystem at the global scale. For this purpose, we introduce shrub into the Canadian Land Surface Scheme (CLASS) as its fifth plant functional type. Then we use CLASS to simulate shrubland's radiative and hydrological processes in Fluxnet sites of the US and the Mediterranean. Offline CLASS runs overestimate evapotranspiration (ET) and underestimate runoff, which is mainly attributable to the overestimation of soil evaporation in wet seasons. In addition, too earlier depletion of soil water by soil evaporation leads to the consequent underestimation of shrub transpiration in the dry seasons, especially in the Mediterranean sites where the seasonal variations of precipitation and temperature are out of phase. We address this problem by reducing soil evaporation (which dominates ET in the wet seasons) and increasing shrub transpiration in dry seasons. Reasonable simulation of shrub's biophysical processes in semi-arid regions is the first step of realistic representations of shrub's biochemical processes there.

Evaluating consistency of modelling-based and data-based water budget approaches over large river basins in Canada

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Estimating the terrestrial water budget at regional or continental scales is essential for understanding and predicting water availability for human use and informing policy managers for planning and decision-making. The increasing availability of various remote sensing-based products for different water budget components makes it possible to better evaluate the water balance and its uncertainty. Given the scarcity of direct in-situ measurements, it is vital to evaluate the consistency of data acquired using different approaches, including both satellite products and model simulations. In this study, we utilize 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)), and one source of water storage data (the Gravity Recovery And Climate Experiment (GRACE)). We then study the uncertainty of each component by a modelling-based water budget approach in which a macroscale hydrological model, the Variable Infiltration Capacity (VIC), is employed to simulate streamflow by constraining the model with evapotranspiration and water storage data. The ability of VIC to close the water budget is assessed across 20 Canadian river basins of size ranging from 90,900 to 1,679,100km² over the period 2002-2014 by comparing to observed streamflow. The estimated streamflow as a residual of the water budget using a data-based water budget approach is also used for comparison. Assessing the water budget closure and its uncertainty over Canada is important for improving the understanding of cold region hydrological processes and their role in the global water cycle.

Preferred Platform: Poster Presentation

Student Presenter: N

CGU_H_11: Diagnostic, Sensitivity, and Uncertainty Analysis of Earth and Environmental Models

Conveners: Shervan Gharari¹, Saman Razavi², Amin Haghnegahdar³, Steven Weijs⁴

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

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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 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.

Preferred Platform: Oral Presentation

Student Presenter: Y

Quantifying uncertainty in historical and projected future snowmelt-driven streamflow in the Grand River watershed, Ontario

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The freshet (characterized by an increase in streamflow driven by the melting snowpack) is a critical period for watershed management and reservoir operations, and climate change is expected to have an impact on this key hydrologic feature globally. In the Grand River Watershed (GRW), the largest watershed in Southern Ontario, the freshet is a critical time of year for managing water supply and reservoir use. This project aims to quantify the uncertainty in the freshet in the GRW, using both observational records and projected future climate change scenarios. Uncertainty arises from several different sources in both historical and projected streamflow and climate conditions, including uncertainty in true baseline conditions, which future climate change scenario will be realized in the future, and in climate model spread, among other sources. Metrics used to measure the freshet in this study include the annual timing and magnitude of the snowmelt pulse, both of which are directly influenced by changes to the annual snowpack forming, building, and melting. The climate conditions driving the freshet are also studied. Preliminary results suggest that in observational records, the freshet occurring two weeks earlier on average is possible, with potential for greater variability in the timing in more recent years. There is also evidence that with each intensified warming scenario, the freshet occurs earlier than the mean baseline and observational freshet. Results will aid in understanding regional hydrologic shifts in the GRW as climate change progresses, and allow for adaptation of watershed management planning in the face of uncertain future conditions.

Preferred Platform: Oral Presentation

Student Presenter: Y

How Correlated is Nash Sutcliffe Efficiency (NSE) To Model Utility? An Assessment Using Decision Crash Testing (DCT).

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Theoretical, computational and experimental advances have led to easier access to more complex and robust hydrologic models. Hydrologic models are used to support decision making by water managers and stakeholders. Unfortunately, models' capabilities and uncertainties aren't readily evaluated or communicated. NSE is one of the most widely used model quality diagnostics in hydrology. However, there are two main issues with using NSE to describe models used to inform decision making. First, despite the popularity within the hydrology community, most people without training in hydrology are unfamiliar with NSE. Second, even within the hydrology community, experts have varied opinion on what a "good" NSE is. The "goodness" of NSE may depend on multiple factors (hydrologic complexity of basin, data availability, resources spent on model, validation methods, and intended use of model). Through the DCT, which explicitly evaluates a model's skill at informing specific decisions, the NSE is correlated to a model's decision-support capability. In the test case, a hydrologic model is used to evaluate two reservoir operation rule curves, based on ecological and economic impacts. Synthetic realities are generated through Generalized Likelihood Uncertainty Estimation of parameters. Each synthetic reality is operated using both rule curves to determine the preferred rule curve for a given parameter set. Then, the model is calibrated to the synthetic realities' inflows at incremental NSE values. For each calibration, the model is evaluated on whether the model prefers the same rule curve preferred by the synthetic reality. After thousands of parameter set realizations, each incremental value of NSE is assigned a percentage of correct decisions made. Using the correlation, the model's capabilities and uncertainties are clearly quantified and communicated to stakeholders. Results indicate NSE is moderately correlated to model utility, and should be used carefully.

Preferred Platform: Oral Presentation

Student Presenter: Yes

Explicitly accounting for climate and flow data uncertainty in hydrologic model calibration

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This study proposes an approach of explicitly accounting for data uncertainty in hydrologic model calibration. Compared with traditional model calibration approaches, this approach has two key aspects. First, it uses multiple realizations of forcing and response data instead of a deterministic data series in calibration. Second, it modifies the goodness-of-fit indicator to account for response data uncertainty in the process of model performance evaluation. In our calibration experiments, precipitation and temperature uncertainties are represented by the Gridded Ensemble Precipitation and Temperature Estimates dataset (Newman et al., 2015), flow uncertainty is derived from the rating curve uncertainty estimation. Results in 20 Quebec catchments show that explicitly incorporating data uncertainty reduces the inaccurate flow predictions caused by inferior quality climate measurements and improves the overall performance of ensemble flow predictions based on a variety of performance metrics.

Preferred Platform: Oral Presentation

Student Presenter: Yes

Hydrologic model sensitivity to potential evapotranspiration inputs

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Understanding the impacts of input data quality on model performance, parameterization, and process fidelity is essential to understanding how to improve hydrologic models. Given the fact that many catchments are confronted with limited data, this knowledge is also important for optimizing data collection campaigns. In this study, we explore the sensitivity of GR4J model parameterization and performance with respect to four different potential evapotranspiration (PET) products of varying quality (from mean monthly pan to daily Hargreaves-Samani modeled PET). The analysis framework is applied to a subset of 57 catchments contained within the MOPEX data set. The selected catchments are distributed across eight eco-regions of the conterminous USA and have been further classified as energy- or water-limited using the Budyko framework. Changes in model parameterization and performance were assessed under both direct (same PET product used for both periods) and cross (different PET products used between periods) validation schemes. The results highlight the importance of energy/water availability in determining model sensitivity, while eco-regions showed no discernable impact. Catchments at the water-limited end of the spectrum exhibited little sensitivity to the quality of the PET inputs, across calibration and validation periods. In contrast, energy-limited catchments resulted in notable differences in model performance and parameterization.

Preferred Platform: Oral Presentation

Student Presenter: N

Determining current uncertainty in discrete soil moisture measurements using a large scale lysimeter facility

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Vertical profiles of soil moisture, measured with soil moisture probes, are commonly used for the characterization of the agricultural soil water budget. Estimation of the total soil water content found within the soil profile requires a vertical interpolation between the probe measurements. Yet, the uncertainty produced through an interpolation is not known; thus, impacting water budget models and estimations. This research used a state-of-the-art lysimeter facility located at the Elora Research Station (Elora, Ontario, Canada) to quantify soil water uncertainty when using discrete soil moisture measurements at five depths using Trime Pico TDR probes installed within 18 high precision weighing lysimeters. The interpolated soil water masses were compared to lysimeter masses over three periods (selected during non-growing and snow-free periods), where an estimation could be made of the uncertainty produced when a vertical interpolation was conducted. By converting matric potential, measured using a tensiometer, to volumetric water content at the lower boundary of the lysimeter, the lower boundary was able to be included in analysis, thereby improving accuracy of the interpolation. The results were divided between the 18 lysimeters based on soil type (loam and sand), with an average of both soil types estimated over the time periods. It was determined that vertical interpolation of discrete soil moisture estimates resulted in 15% uncertainty of the water budget for loam soils and 11% within sandy soils. This uncertainty is well above the uncertainty of the TDR probes, thus suggesting innovative approaches for vertical interpolations to be developed and that estimates of the water budget developed using this vertical interpolation of discrete soil measurements be interpreted based on this potential uncertainty.

Preferred Platform: Poster Presentation

Student Presenter: Y

Reducing Error Between Satellite and in situ Soil Moisture over Canadian Croplands

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NASA's Soil Moisture Active Passive (SMAP) satellite was launched to monitor global soil moisture. The satellite mission has proved successful based on assessments over many regions of the globe when compared to in situ data. Despite overall success, there have been inconsistencies identified in retrievals over agricultural and forest lands. As a result, efforts to improve retrievals over these regions is of importance for monitoring crop production and the impact of drought and other soil moisture extremes on food security. To this end, a recent soil moisture field experiment, (SMAPVEX16) was held at a research watershed near Carman Manitoba in June and July 2016. The Carman site is also used as a primary location for the ongoing validation and calibration of the SMAP soil moisture retrieval products. During the experiment, ground-based L-Band radiometers (similar frequencies and observation angles used on the SMAP satellite) were placed over winter wheat and canola crops for the duration of the experiment. These observations were used to investigate if commonly used vegetation parameterizations contribute to the reduced accuracy in estimating soil moisture in these dynamic vegetated areas. We examined potential changes to crop parameterization that will improve retrieval accuracy over the winter wheat and canola growing cycle, using CMEM (Community Microwave Emission Model). Radiometer observed microwave brightness temperatures were compared to modeled brightness temperatures based on parameterizations derived from in situ observed parameterizations (e.g LAI, VWC). Preliminary results suggest an overestimation of modeled brightness temperature over winter wheat but an underestimation over canola. Although we observe no statistically significant relationships among differences between the observed and modeled brightness temperature based on input data, we anticipate that further calibration of the vegetation parameters will reduce observed errors.

Preferred Platform: Poster Presentation

Student Presenter: Y

Characterizing uncertainties in flood inundation modelling in urban environments

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Flooding, as a major natural disaster worldwide, threatens human lives and causes billions of dollars in damage each year. Accurate estimations of flood inundation parameters (i.e. depth, extent, among others) are crucial for future design and planning of societies and infrastructure especially in densely-populated urban areas. Despite significant advancements in hydrodynamic models, there are various sources of uncertainties that can underlie the reliability of flood inundation models. The objective of this study is to investigate the uncertainties associated with channel/floodplain roughness, river cross sections, and design hydrographs based on a probabilistic flood modelling approach. Ground-based streamflow observations, design hydrographs, river bathymetry data, existing structures including buildings, culverts, bridges, tributary in-flows, and diversions, channel and floodplain roughness, and high-resolution DEM (LiDAR data at 1m resolution) are used to develop and validate HEC-RAS-v5 over a reach of the Rideau River in the city of Ottawa. High-resolution topographic data is used to represent complex urban features, capture microscale blockage effects and simulate complex flow paths around buildings and structures. Downstream flow rating curves as well as observations of flood extents based on ground-based measurements and satellite imagery are used for model verification. Various roughness coefficient values are sampled based on a hypercube sampling approach from a predefined range that is determined using land cover information. The effects of three different cross-section shapes on the simulated flood characteristics are analyzed. An ensemble of flow hydrographs is generated using observed water levels and rating curve parameter distributions. Results indicate the importance of characterizing uncertainties in flood inundation modelling. Multi-modelling is shown to improve single model implementation and provide more reliable flood estimations.

Preferred Platform: Poster Presentation

Student Presenter: Y

CGU_S_01: Structure and Dynamics of the Continental Lithosphere and Upper Mantle

Conveners: Fiona Darbyshire¹, Qinya Liu^{2,4}, Andrew Schaeffer³, Russ Pysklywec⁴, Andrew Frederiksen⁵

Co-chairs: Fiona Darbyshire, Qinya Liu, Andrew Schaeffer, Russ Pysklywec

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Structural Variation Along the St-Lawrence Rift : Evidence From Receiver Functions and Seismic Anisotropy

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The St-Lawrence region in eastern Canada has experienced multiple Wilson cycles through the last ~1 Ga. The rocks of the North shore belong to the Grenville Province, a ~1 Ga old orogenic belt of similar scale and character to the present-day Himalayan collision. Rifting associated with breakup of the supercontinent Rodinia was followed by the Paleozoic Appalachian orogeny. Appalachian terranes make up the region south of the St-Lawrence valley and the boundary is situated beneath the river. Additionally, the Charlevoix area preserves structures from a ~350 Ma meteorite impact, whose crater remains visible in the North shore topography. The relict orogenic and rift structures, along with the impact structure, serve to focus intraplate seismicity along the St-Lawrence and around the Charlevoix-Kamouraska zone. The St-Lawrence valley is now well-sampled by broadband seismic stations, including permanent stations of the Canadian national network and temporary stations installed by the Geological Survey of Canada, the EarthScope project and McGill University. The new stations allow both cross-rift and along-rift variations to be observed, along with a detailed assessment of the effects of the Charlevoix impact. Receiver-function analysis using H-k stacking and velocity-depth modelling shows new details of crustal structure variation along and across the St-Lawrence region. The Moho depth varies from ~36 to 45 km, and the transition ranges from relatively sharp to highly gradational. The receiver functions also indicate the presence of multiple intra-crustal discontinuities, along with significant lateral heterogeneity and/or anisotropy. Seismic anisotropy, measured using SKS splitting, shows a dominant E-W fast orientation, with a systematic rotation along the St-Lawrence valley. Contributions from both “fossil” lithospheric fabric and present-day mantle flow are likely in this context.

Preferred Platform: Oral Presentation

Student Presenter: N

Magmatic Imprints of Ocean and Continental Slab Removal in the Mediterranean

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The transition from retreating ocean lithosphere subduction to the continental mantle lithosphere peeling back (delamination) has been increasingly recognized for the geodynamic evolution of Alboran domain, Apennines, Southeast Carpathians and Anatolia and probably other parts of the Mediterranean region. As such, the migratory pattern of surface features (basin formations), exhumation of HP rocks and the modification in magma chemistry (e.g subduction related to intraplate-style) are all presumably related with the large scale lithospheric evolution. In this work, our main focus is on the magmatic variation of these orogens in the Mediterranean since the last 20 Ma. We used numerical geodynamic experiments in which we compare and contrast model predictions against the inferences made by geochemistry data from several sources. Here, we consider 400 km wide subduction accretionary complex that represents the material derived from the Neotethys subduction. The formation of the volcanic arc at the initial stage and the further development of the melting by decompression of the mantle occurs in all experiments. The latter is formed by the removal of the oceanic slab under the accretionary complex. The prograssive evolution of the melting in relation to the slab removal develops in majorly two phases and each time the hydrated melt mixes with the decompression melt. The volumetric melt production calculations are used to reconcile with the model results for the putative change in the orogenic to anorogenic magmatism proposed in the Mediterranean hinterlands to forelands. The detachment of the slab at the ocean to continental plate transition (at depths from 130-300 km) does not play a pivotal role as suggested by previous workers.

Preferred Platform: Oral Presentation

Student Presenter: N

A Three-dimensional Paradigm for Subduction in the Modern Age

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Advances in high-performance computing and the influx of seismic data allow for an unprecedented level of detail to be incorporated in geodynamic models. However, few open source software packages exist to assimilate data into a three-dimensionally realistic configuration of a modern plate boundary. Here, I present a comprehensive three-dimensional (3D) structure for Alaska, AlaskaModel 1.0, produced with the open source program, PlateBoundaryGenerator. Next, I show the transformative influence of incorporating a high-resolution, geologically realistic plate configuration into 3D geodynamic models of deformation at the Pacific-North American plate boundary in Alaska. Through this workflow, the geodynamic models produce (1) the first self-consistent explanation for the far-field location of the tallest mountain in North America, Denali, (2) a physical mechanism for the motion of the Wrangell block forearc sliver, and (3) a geodynamic explanation for the anomalous Wrangell volcanics.

Preferred Platform: Oral Presentation

Student Presenter: N

Structure, dynamics, and evolution of the continental lithosphere beneath the Central Appalachians

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The eastern margin of North America has undergone multiple supercontinent cycles over the past billion years, yielding the surface geology and topography visible today. It is poorly known, however, how the crust and mantle lithosphere have responded to these tectonic forces, and how geologic units preserved at the surface relate to deeper structures. The MAGIC experiment, part of the EarthScope USArray Flexible Array, was a linear, broadband passive seismic array deployed across the central Appalachians from 2013-2016. New images of the crust and upper mantle derived from MAGIC data are shedding new light on the deformation and evolution of the lithosphere during multiple phases of orogenesis and rifting. Specifically, we observe a sharp change in crustal thickness across the eastern edge of the Appalachians, with a deeper Moho beneath the mountains than suggested by simple isostatic models. Intracrustal structures are revealed via receiver function analysis and may reflect relict shear zones from past episodes of subduction. We find evidence for a relatively shallow lithosphere-asthenosphere boundary (LAB) beneath the Appalachians, with the thinnest LAB beneath the present-day high topography, adjacent to the location of Eocene volcanism in and around Harrisonburg, VA. This observation is consistent with lithospheric loss as a mechanism for Eocene volcanic activity. Observations of seismic anisotropy from a combination of SKS splitting, anisotropic receiver function analysis, and Love-to-Rayleigh wave scattering reveals changes in anisotropic geometry laterally and with depth, and argue for the presence of anisotropy within the mantle lithosphere. This lithospheric anisotropy likely reflects deformation due to past episodes of orogenesis and rifting. Taken together, these results yield new insight into the structure and evolution of the central Appalachians.

Preferred Platform: Oral Presentation

Student Presenter: N

**Geophysical search for lithospheric boudinage in the Grand Banks region offshore
Newfoundland**

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The evolution of the Lofoten-Vesterålen margin offshore Norway has been studied in great detail, especially concerning the stress regimes and rheological parameters involved in associated extensional rifting episodes. It is suggested that the presence of crustal undulations is due mainly to lithospheric boudinage-forming mechanisms. Boudinage features are segments within the subsurface formed during lithospheric stretching and rifting, which begin as pinch-and-swell structures among structurally competent layers of strata bound by incompetent layers, and later separate into discrete boudins. One characteristic of these structures is crustal thinning – or necking – among competent layers, which is often apparent in seismic sections. This feature has also been observed between northwest France and southern Italy, representing another example of lithospheric boudinage. Offshore Norway, these structures are seen through alternating density variation patterns seen in gravity observations. Moreover, the presence of listric faults and Moho undulations are thought to be related to these regimes and can be seen through magnetic and seismic surveys. The purpose of this investigation is to apply the same approach to the Grand Banks region offshore Newfoundland, which is an analog to the Lofoten-Vesterålen margin in that it is also an economically valuable location which evolved under similar conditions. The features described offshore Norway could reasonably be expected to appear in the Grand Banks due to the similar extensional rifting and tectonic history of the area. From seismic, magnetic and gravity data, interpretations are made to determine if the same structures as those observed offshore Norway are present in the Grand Banks region. The application of these methods to the Grand Banks is valuable due to the economic prospects, the potential for increasing geological knowledge of the area, as well as validating existing model results of extensional margin evolution.

Preferred Platform: Oral Presentation

Student Presenter: Y

Geodynamic modeling of Mid-Continental Rift and mantle plume interactions under Precambrian mantle conditions

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The Mid-Continent Rift System (MCRS) is a 3000-km long failed rift system that formed within the Precambrian continent of Laurentia and nearly split North America apart about 1.1 billion years ago. The MCRS can also be classified as a Large Igneous Province (LIP), made up of two distinct magmatic phases [Stein et al., 2015]. The first, large-scale magmatism, is characterized by a large volume of flood basalt that filled a fault-controlled basin. The second, post-rift, phase consists of volcanics and sediment that were deposited in a thermally subsiding basin after faulting ended. This flood basalt filled rift geometry is a special characteristic of the MCRS that is not observed in other presently active or ancient rifts. Hence the MCRS's unusual nature likely reflects the combined effects of rifting and a mantle plume. We investigate this hypothesis with a geodynamic model by fully exploring the parameter space for a range of mantle potential and plume excess temperatures under different extension scenarios and lithospheric/plume structure. We find, that for a rapid extension rate and for present-day mantle potential temperatures (~1343 oC), a mantle plume is required with an excess temperature 100 oC to generate the required volume of flood basalt for an initial 100 km thick continental lithosphere. On the other hand, we find that models with higher mantle potential temperatures 1453 oC do not require the presence of a plume.

Preferred Platform: Oral Presentation

Student Presenter: N

Attenuation variations between the eastern Canadian Shield and Appalachian Orogeny

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Spatial variation in seismic attenuation across tectonic zones has implications for seismic hazard at regional scales. In addition to providing insight into regional tectonic history and geodynamic processes, these spatial variations affect the level of shaking from an earthquake. The St. Lawrence River hosts several of the most seismically active regions in eastern Canada and marks the boundary between Appalachian and Shield lithosphere. Although current seismic hazard models consider a uniform crustal and attenuation structure across eastern Canada, there is increasing evidence for differences in attenuation between the Shield and Appalachians, with higher attenuation in the latter. Magnitude residuals of earthquakes occurring along the Shield-Appalachian boundary are lower at stations on Appalachian crust at local and regional distances. Ground motions predicted from peak amplitudes of Lg arrivals exhibit a similar trend, indicating higher attenuation in the Appalachians.

Preferred Platform: Oral Presentation

Student Presenter: No

Unraveling the dynamics of orogenesis and intracontinental deformation in the Canadian Arctic: Results from tectonic analogue models

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Orogenesis on Ellesmere Island (Canadian Arctic) is related to many tectonic stages, however the dynamic conditions to initiate deformation in an intraplate setting is not well understood. It has recently been related to inherited structures in the deep lithosphere. However, rheology is also a primary factor affecting the kinematics in the lithosphere. To address the role of rheology and pre-existing structures, we designed a set of scaled analogue experiments. The study tests: a) the presence and absence of a pre-existing structure or weak zone in the lithospheric mantle; and b) the effects of rheological strength using a weak and normal lithosphere. The layered model of a brittle upper crust, viscous lower crust and lithospheric mantle are deformed in a convergent setting. Tectonic evolution of the model is recorded using high spatial and temporal cameras. From this setup, a time-series dataset of the velocity field and strain in the model is acquired. Deformation in models with a weak zone is accommodated by displacement along the zone that propagates into the overlying lower and upper crust. In contrast, models absent of a weak zone display ductile folding and thickening of the viscous layers and flexural shearing of the brittle upper crust. These models consist of a weak lithosphere. Models with a normal lithosphere and a weak zone, displacement is entirely along the weak zone causing the lithospheric mantle to subduct into the asthenosphere. Deformation in a weak lithosphere is diffuse than in a normal lithosphere. Thus, the rheological strength of the lithosphere dictates how the strain is distributed laterally. We also conclude that although the rheological properties play an important role in the kinematics of deformation in the lithosphere, the presence of a weak zone is the driving force. This research adds to the understanding of not only the kinematic conditions of intraplate deformation on Ellesmere Island but also intraplate tectonics generically.

Preferred Platform: Oral Presentation

Student Presenter: No

Rayleigh wave phase-velocity variations in southeast Canada and the northeast USA: A detailed look at the Appalachian lithosphere

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Eastern Canada consists of three major tectonic provinces: the Appalachians, Grenville and the Superior craton. This region has experienced over 3/4 of the Earth's geological history, and studying this area is key to answering fundamental questions about the evolution of continental lithosphere. To address this issue, we use Rayleigh wave tomography using a two plane wave technique to constrain deep crustal and upper mantle structure beneath southeast Canada and the northeast USA, a region that includes mostly Phanerozoic Appalachian and Proterozoic Grenville domains. Previous studies have shown that the seismically slowest domain in the region is the Appalachian domain. However, the resolution of the presented models, especially in the eastern part of that area, is still low due to lack of sufficient data. A good start would be to have some information about phase velocity variations at a regional scale within the study area. In this study we will present more detailed information about phase velocity perturbations, as a result of having access to the data from recently-installed stations of the QMIII seismograph network, and a better azimuthal coverage than previously available. We use the data from 71 broadband stations from 6 different seismograph networks. More than 310 earthquakes with a minimum magnitude of 6.0 are processed and 46 of them are chosen to be input to the two plane wave inversion. Combining the high-quality and well-dispersed fundamental mode Rayleigh wave data from summer 2013 to summer 2015, we present a set of maps showing lateral variations of phase velocity at several periods and discuss their tectonic implications.

Preferred Platform: Poster Presentation

Student Presenter: Y

Crust and mantle deformation beneath southern Peru and Bolivia: constraints from receiver functions and seismic anisotropy

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Subduction systems play a key role in plate tectonics, but the deformation of the crust and uppermost mantle during subduction and orogenesis in continental subduction systems remains poorly understood. Observations of seismic anisotropy can provide important constraints on dynamic processes in the crust and uppermost mantle in subduction systems. The subduction zone beneath Peru and Bolivia, where the Nazca plate subducts beneath South America, represents a particularly interesting location to study subduction-related deformation, given the complex slab morphology and the along-strike transition from flat to normally dipping subduction. In this study we constrain seismic anisotropy within and above the subducting slab (including the mantle wedge and the overriding plate) beneath southern Peru and Bolivia using transverse component receiver functions. Because anisotropic receiver function analysis can constrain the depth distribution of anisotropy, this analysis is complementary to previous studies of shear wave splitting in this region. We examine data from two long-running permanent stations NNA (near Lima, Peru) and LPAZ (near La Paz, Bolivia). NNA overlies the Peru flat slab, while LPAZ overlies the normally dipping slab beneath Bolivia. A single-station stack, harmonic decomposition techniques, and rose diagrams all were used to constrain the present of anisotropic interfaces within the crust and upper mantle. We found evidence for different multi-layer anisotropy some with dipping interfaces and/or dipping symmetry axis underneath each region. The crustal anisotropy interfaces imply a change in the deformation regime or a change in the mechanism of anisotropy with depth, both may contribute to our understanding of deformation within the orogen.

Preferred Platform: Poster Presentation

Student Presenter: Y

Dynamics of lithospheric extension and anomalous topography in southern Tibet: A case for mantle flow driving crustal tectonics

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The Himalayan-Tibetan orogen has been created by the Indo-Eurasia collision over the past ~50 Ma and comprises 2600 ± 900 km of shortening accommodated by crustal thickening. Although the north-south (N-S) convergence between India and Eurasia is continuing, the present active deformation in southern Tibet is characterized by north-south trending rifts, suggesting a coeval east-west (E-W) extension tectonic regime. Geodetic observation and Earthquake focal mechanisms also show that deformation is dominated by E-W extension across these N-S trending rifts. Gravitational collapse, oblique convergence, and mantle upwelling are among possible mechanisms responsible for the enigmatic east-west extension of southern Tibet. We employ a 3D-spherical control volume geodynamic model of the present-day mantle flow to understand the relationship among topographic features, intermediate-depth earthquakes, and tectonic stresses induced by mantle processes. The thermal structure of the mantle and crust is obtained from a new seismic P-wave velocity model. The resulting dynamic topography shows that surface uplift driven by thermally buoyant mantle upflow coincides with the northern Himalaya and southern Lhasa terrane, where several south-north trending rifts dominate. Crustal subsidence occurs in the northern Lhasa terrane and along the Main Frontal Thrust. The positions of uplift and subsidence agree well with the vertical velocity field derived from GPS measurements. We also show a correlation among the spatial distribution of intermediate-depth earthquakes (70 ~ 120 km), surface rifts, and the topographic uplift, implying that small-scale upwelling mantle flow is contributing to the observed E-W extension. We infer that the E-W extension and rifting in southern Tibet driven by the small-scale shearing mantle upwellings is caused by partial delamination of the underthrusting Indian lithosphere.

Preferred Platform: Poster Presentation

Student Presenter: N

**Upper Mantle Structure Beneath the Diamondiferous Central Slave Craton, Canada, from
Teleseismic P and S Body Wave Tomography**

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Over the past number of decades, the Slave Craton (Canada) has been extensively studied for its diamondiferous kimberlites. Not only are diamonds a valuable resource, but their kimberlitic host rocks provide an otherwise unique direct source of information on the deep upper mantle (and potentially transition zone). Many of the Canadian Diamond mines are located within the Slave Craton. As a result of the propensity for diamondiferous kimberlites, it is imperative to probe the deep mantle structure beneath the Slave Craton. This work is further motivated by the increase in high-quality broadband seismic data across the Northern Canadian Cordillera over the past decade. We used 77 stations from eight different seismic networks such as the Canadian National Seismic Network (CNSN), Yukon Northwest Seismic Network (YNSN), the older Portable Observatories for Lithospheric Analysis and Research Investigating Seismicity (POLARIS), USArray Transportable Array (TA), older Canadian Northwest Experiment (CANOE) and the Yukon Observatory (YO). We have, then, generated a P and S body wave tomography model of the Slave Craton and its surroundings using P, S, SKS and ScS relative delaytimes from teleseismic earthquakes. Furthermore, tomographic inversion techniques are growing ever more capable of producing high resolution Earth models which capture detailed structure and dynamics across a range of scale lengths. Here, we present preliminary results on the structure of the upper mantle underlying the Slave Craton.

Preferred Platform: Poster Presentation

Student Presenter: Y

Deformed but stable: a shear velocity model of the lithosphere in central Canada and the north-central United States

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As seismic tomography captures a snapshot of present-day structure, it is useful to have these snapshots from a wide variety of stages in the Wilson cycle, to better understand each active tectonic setting as well as the transitions between them. Due to the hazard posed by many active tectonic regions, they are often the focus of seismic studies; areas such as the Canadian Shield, much of which has not seen any activity for ~1 billion years, are sometimes neglected, but they hold a unique window into long-term lithospheric evolution. To take our snapshot of the shield, we combine available data from seismic networks spanning the mid-latitudes of the United States north to Hudson Bay, Canada, and eastern Manitoba to western Quebec. We select 80 stations with ~200 km spacing, resulting in dense path coverage of a broad area centered on the Great Lakes. We use teleseismic data for Mw6+ earthquakes from 2005-2016, and make Rayleigh wave two-station dispersion measurements for all station pairs with suitable event-station geometry. We invert these measurements for anisotropic phase-velocity maps at discrete periods between 20 and 220 s. From this suite of phase velocity maps, we invert for 1-D shear velocity models at each grid node. These models are combined to make a pseudo-3-D Vs model covering the study area. We examine the shear velocity structure beneath specific features, with a particular focus on the Mid-Continent Rift (MCR), which appears in short period phase-velocity maps as a slow anomaly. We test the depth extent of low velocities required to produce this signal, and look for variations in the lithosphere associated with the MCR. We compare the shear velocity structure beneath the fast Superior Craton and the (relatively) slow Trans-Hudson Orogen. Variations in anisotropy with depth become clearer in the pseudo-3-D model; we examine contrasts in direction and magnitude that might indicate the base of the lithosphere.

Preferred Platform: Poster Presentation

Student Presenter: N

Geodynamic Modelling of Accretion of Micro-Continental Blocks

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When a micro-continental block (island arc, seamount etc.) reaches to a subduction channel, it may change the fate of that subduction system various ways depending on its dimensions and rheology. We designed several numerical geodynamic modelling setups to investigate some of the possible geodynamic ideas such as subduction of the micro-continental block or accretion of the micro-continental block to the overriding plate and subsequent subduction initiation. We experimented previously mentioned ideas for both of the continent-ocean and ocean-ocean type subduction settings. Moreover, we tested variously sized micro-continental blocks ranging from 100 to 450 km, different rheological properties for the mantle lithosphere of the micro-continental block such as dry or wet olivine, and varying convergence velocities from 0 to 4 cm/yr. Preliminary results show that the rheology of the mantle lithosphere controls the possibility of the slab break-off following the accretion of the micro-continental block. Our results also show that subduction initiation process starts easier after a break-off when imposed convergence is given. Moreover, micro-continental block experiences extensional stress and thinning before the continental collision regardless of block's size and convergence velocity due to the slab-pull force.

Preferred Platform: Poster Presentation

Student Presenter: Y

Sensitivity kernels for multi-component ambient-noise cross-correlation functions, with application to southern California crust

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We develop a general theory to calculate multi-component [e.g., vertical-vertical (Z-Z), transverse-transverse (T-T), and radial-radial (R-R)] sensitivity kernels for empirical Green's functions (EGF) from ambient noise based on full numerical simulations of seismic waves and adjoint method. The Z-Z component sensitivity kernel can be constructed from the convolution of the forward field from a delta-function vertical point force at source and the adjoint field due to an Z-Z component adjoint source injected at the receiver in the vertical direction. In comparison, a T-T component kernel can be obtained by the summation of two rotated kernels, each of which is constructed from the interaction of a forward field due to a delta-function point force in the east or north direction, and an adjoint field by injecting T-T component adjoint source in the east and north direction at individual receivers with proper amplitude modulation factors; the sensitivity kernel for R-R component measurement is similar to those of T-T component kernels except with different amplitude modulation factors. The rotation relations for seismograms, individual and event misfit kernels are validated through a series of numerical simulations and our results show the rotated kernels are almost identical to the reference ones with less than 1% error, sufficient for adjoint tomographic inversion.

With the ability to compute kernels for multi-component EGFs, we performed adjoint tomography of EGFs from Z-Z and T-T component ambient noise at 5-50 s in southern California. After five iterations, we successfully obtained an improved Vsv model from Rayleigh waves (Z-Z) and Vsh model from Love waves (T-T), respectively. Compared to the initial model from earthquake-based adjoint tomography, our improved models show better waveform fitting with reduced misfit, and reveal several new interesting velocity features. Positive ($V_{sh} > V_{sv}$) radial anisotropy is observed in the whole uppermost mantle ($\sim +7\%$) and the north-eastern part of the crust ($\sim +4\%$). In contrast, the whole Transverse Range shows negative ($V_{sh} < V_{sv}$) radial anisotropy ($\sim -6\%$) in the middle-to-lower crust (15-25 km).

Preferred Platform: Poster Presentation

Student Presenter: N

High-resolution 3D simulations of continental extension

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Observations of rifted margin structure suggest continental breakup occurs through distinct phases of extension. Early rifting stages often exhibit distributed normal faulting in the upper crust, which remains decoupled from deformation in the lower crust and upper mantle. Further extension commonly marks a transition to coupled deformation along lithospheric-scale detachment faults. Here, we use high-resolution 3D simulations of continental extension to examine how large-scale detachment faults evolve from distributed normal faults in the initial stages of extension. The numerical simulations are developed with the finite-element code ASPECT, which efficiently solves for non-linear deformation in the lithosphere and convecting mantle. The model spans 500 km and 100 km, respectively, in the horizontal and vertical directions. The model length is systematically varied (5-500 km) and velocity boundary conditions drive extension. The initial lithospheric structure contains a geothermal profile characteristic of the continental lithosphere and compositional layers representing distinct portions of the crust and mantle. These layers feature distinct thermodynamic and constitutive properties, with deformation accommodated by a combination of dislocation creep and brittle failure via a Drucker Prager plastic yield criterion. To promote deformation localization, the internal friction angle and cohesion weaken as plastic strain accumulates. Rather than initiating deformation with a single zone of weakness, we apply an initial random perturbation to the plastic strain field, which reproduces distributed normal faulting during the early stages of extension. In models with lengths greater than 100 km, laterally offset detachment faults form as distributed normal faults merge and deformation focuses. These results suggest that significant heterogeneity may develop along rifted margins in response to the natural evolution of initially widely distributed normal fault systems.

Preferred Platform: Poster Presentation

Student Presenter: N

**CGU_S_02: Induced Seismicity in Canada and the USA: Lessons Learned and
Recommendations for Partnerships and Potential Directions**

Conveners: Hadi Ghofrani¹

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Influence of Lithostatic Stress on Earthquake Stress Drops in North America

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We estimate stress drops for earthquakes in and near the continental United States using the method of spectral ratios. The ratio of acceleration spectra between collocated earthquakes recorded at a given station removes the effects of path and recording site and yields source parameters including corner frequency f_c and the ratio of seismic moment between the two earthquakes. We determine stress drop from these parameters for 1121 earthquakes greater than $M \sim 3$ in 60 earthquake clusters. We find that the average Brune stress drop for the few eastern United States (EUS) tectonic mainshocks studied (2.6-36 MPa) is about three times greater than that of tectonic mainshocks in the western United States (WUS, 1.0-7.9 MPa) and five times greater than mainshocks potentially induced by wastewater injection in the central United States (CUS, 0.6-5.6 MPa). EUS events tend to be deeper thrusting events, whereas WUS events tend to be shallower but have a wide range of focal mechanisms. CUS events tend to be shallow with strike-slip to normal-faulting mechanisms. With the possible exception of CUS aftershocks, we find that differences in stress drop among all events can be taken into account, within one standard deviation of significance, by differences in the shear failure stress as outlined by Mohr-Coulomb theory. The shear failure stress is a function of vertical stress (or depth), the fault style (normal, strike slip, or reverse), and coefficient of friction (estimated here to be, on average, 0.64). After accounting for faulting style and depth dependence, we find that the average Brune stress drop is about 3% of the failure stress. These results suggest that high-frequency shaking hazard (~ 1 Hz) from shallow induced events and aftershocks is reduced to some extent by lower stress drop. However, the shallow hypocenters will increase hazard within several kilometers of the source.

Preferred Platform: Oral Presentation

Student Presenter: No

Earthquakes induced by hydraulic fracturing are wide-spread in Oklahoma

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Wastewater disposal is primarily responsible for the increased seismicity rate in Oklahoma within the past decade, but no statewide analysis has sought to analyze the contribution of hydraulic fracturing (HF) to the observed seismicity or the seismic hazard. We collected all available information on timing and location of HF in Oklahoma in the past decade to evaluate their relationship to seismicity. Utilizing an enhanced seismicity catalog generated with multi-station template matching from 2008-2016, we were able to identify ~100 earthquake sequences that are closely correlated in space and time with HF wells. We were guided to these sequences by calculating a delta earthquake rate for each HF well based on seismicity before, during, and after, and then sorting wells to focus on those with the highest change in rate during stimulation. The cases we identify were spread across a wide area of the state, including the SCOOP, STACK, Ardmore, and Arkoma plays that has been the focus of recent development in the southern and western parts of the state. In some regions, 90% of the seismicity was correlated with reported HF wells, and in some cases 50% of the HF wells were correlated with seismicity. We found nearly 500 earthquakes with magnitudes 2.0, with a maximum magnitude of ~3.5. These findings imply regulations implemented in 2018 that require operators to take action if a magnitude 2 earthquake occurs will have a significant impact on industry.

Preferred Platform: Oral Presentation

Student Presenter: N

**CELLULAR SEISMOLOGY PREDICTABILITY AS A MEASURE OF ASSOCIATION
BETWEEN WASTEWATER INJECTION WELLS AND EARTHQUAKES: A 2018
UPDATE**

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Discerning the interrelated effects of space and time on the potential for wastewater well injection to induce earthquakes in Oklahoma is important for accurately mapping seismic hazards. This study explores how distance from wells and time after initiation of injection affect the possibility that injection activity might induce earthquakes under different conditions of operational lifetime, injection volume, and well depth. The method used here is a modified version of “Cellular Seismology”, which we call “Modified Cellular Seismology” (CS, MCS, e.g., Kafka, 2007; Chambless, 2015; Chambless and Kafka, 2017). We use “CS Predictability” (CSP) as an operational definition of the extent to which injection wells are associated with earthquakes. Using this method, analyses were designed to test the hypotheses that earthquakes associated with injection are more likely to occur close to (i.e., conservatively within about 15 km of) wells and within the same year as active injection, depending on various operational conditions. We find evidence that the potential for inducing earthquakes does extend to about 15 km from injection wells, although we also find that earthquakes are most likely to be between 2-3 km from any given well and second most likely to be between 9-10 km from any given well. Regression analyses suggest that CSP decreases by an average of about 5% over a period of 5-7 years for any given well, though there exists a great deal of scatter in this relationship. This change, if it exists at all, is quite slow and also variable across wells of different conditions, ranging from a decrease of 26% to an increase of 8%. Additionally, analyses on wells active for only a single year show that the relationship between CSP and time may not be linear, as CSP tended to stay constant at first and then peak at least a year after injection. This suggests that there may be, on average, at least a year of lag before any given well is likely to induce earthquakes.

Preferred Platform: Oral Presentation

Student Presenter: Y

Regional Q and Stress Drop for the Central US: Impact on the Induced vs Natural Seismicity Question

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We have completed a regional Q study of the Gulf Coast region and to the west and north in Kansas, Oklahoma, and Texas, and I have also examined stress drops from PIE and natural earthquakes in central and eastern North America (CENA). Average mid-continent $Q(f)$ for CENA has a Q_0 of 525 and η of 0.45. We estimate Gulf Coast regional $Q(f)$ as a Q_0 of 259 and η of 0.715. West and north of the Gulf Coast region we see low 5 Hz Q in central Kansas, central Oklahoma, and northern Texas similar to Gulf Coast 5 Hz Q, but mid-continent Q at 1 Hz. The intensity patterns for the 1886 M7.0 Charleston, SC, the 1957 M5.7 El Reno, OK, the 2011 M5.6 Prague, OK, and the 2016 Mw5.8 Pawnee and Mw5.0 Cushing, OK earthquakes show decay with distance patterns that correlate with our regional Q pattern. Hough's (2014) differences between moment magnitude and intensity estimated magnitude (M_{ie}) are also strongly correlated with regional Q and not stress drop, supporting strong Q/intensity correlation in the central US. I have estimated Brune stress parameters for several Oklahoma earthquakes using estimates of corner frequency from the peak of the tangential component of the velocity Fourier spectrum. Care has been taken to avoid contaminating spectral peaks from leaky-mode surface-waves, nearby-building interactions, and soil resonances. Spectral shape fitting has been avoided. In general, Brune stress parameter for Mw5 Oklahoma mainshocks ranges between 15 and 20 MPa, while aftershocks and smaller magnitude earthquake stress parameters fall in the 1 to 10 MPa range. These values are typical for the south central US potentially induced and natural earthquakes. Other eastern North America regions have natural earthquake stress parameters above 15 MPa, but shallow natural earthquakes can have values in the 2 to 12 MPa range similar to potentially induced earthquakes. Thus, I see no distinction between stress drops from potentially induced and natural earthquakes.

Preferred Platform: Oral Presentation

Student Presenter: N

Automatic detection of seismic events using deep neural networks and polarization analysis of array data

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The recent increase in seismicity in western Canada, largely associated with the development of unconventional hydrocarbons, emphasizes the necessity of a complete earthquake catalogue for ground response analysis and further seismic hazard evaluations. Conventionally, the most reliable automatic algorithm for earthquake detection is waveform matching that measures similarity between pairs of recorded events using cross-correlation. Although it is proven to be robust, the intensive computation time hinders its implementation for large data-set processing. Rapidly growing computational power and advances in machine learning techniques make it possible to develop more efficient algorithms in identifying seismic events. In this study, we develop a near-real-time monitoring system for characterizing seismic activities in northeastern British Columbia (BC) and western Alberta (AB). Based on a comprehensive earthquake catalogue consisting of over 3000 events that occurred during 2014-2016, we train a deep convolutional neural network classifier to discriminate seismic signals from noise. An offline convolutional neural network is designed to extract temporal features from multiple levels of representation of waveform data. Further separation of P- and S-phases is achieved by scaling the first layer of representation of our network using the particle motion parameters of the data covariance matrix associated with body wave propagation. Our results show that the accuracy of automated blind classification reaches an average of 98%. To evaluate the effectiveness of our method, we apply the trained network to study induced seismicity in the vicinity of Fort St. John, BC, recently covered by a dense array of seismic stations. It turns out that the new technique can identify more earthquakes than manually detected events while significantly reducing the processing time.

Preferred Platform: Oral Presentation

Student Presenter: N

Induced seismicity characterization with a shallow-wellbore geophone array and broadband sensors

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The Tony Creek Dual Microseismic Experiment (ToC2ME) is a field program that employed a diverse set of sensors to record a hydraulic-fracturing completion program at a 4-well pad west of Fox Creek, Alberta. The acquisition systems consisted of a 68-station shallow borehole array, six broadband seismometers and one strong-motion accelerometer. This dataset yielded a substantial record of induced seismicity up to MW 3.2, including 4,108 induced events with well determined magnitudes and hypocentres. The largest events have strike-slip mechanisms and are clustered above the treatment zone along well defined N-S lineaments. Several other event clusters are more diffuse and have distinct magnitude characteristics and mechanisms. Horizons extracted from 3-D seismic data reveal several structural fabrics that are subparallel to event clusters, although the microseismic lineaments do not appear to correlate exactly with seismically imaged features. The ToC2ME dataset forms the core for an integrated suite of co-ordinated academic research projects that include construction of a regional geomodel using publicly available data, reprocessing and interpretation of co-located multicomponent 3-D seismic data, development of innovative microseismic processing methods and geomechanical studies.

Preferred Platform: Oral Presentation

Student Presenter: N

Short-term Induced Seismicity Hazard Mapping in Alberta: Preliminary Results

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We present preliminary one-year retro-active hazard maps for induced seismicity in Alberta. These maps will be useful in evaluating the extent to which the potential for induced seismicity alters the pre-existing hazard from natural seismicity. We make a baseline map using seismicity information to 2012. This baseline map will then be updated by producing one-year maps from about 2013 onwards. For these short-term hazard maps we are using one-year seismicity patterns, taking into account the clustered nature of these events using a smoothed-seismicity adaptation of the Assatourians and Atkinson (2013 SRL) EQHAZ software. The ground-motion fields are calculated using the developed ground motion prediction equations (GMPEs) for this region (Novakovic and Atkinson, 2015 SRL; Atkinson et al, 2017 AGU). The combination of the changing overall rate and the changing clustering will result in a different map for each year. The results from this work will be useful to characterize changing hazard rates due to induced seismicity.

Preferred Platform: Oral Presentation

Student Presenter: N

Results from Monitoring Microseismicity in the Rome Trough, Eastern Kentucky

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Identifying and characterizing induced seismicity without baseline microseismicity observations can be problematic. The Cambrian Rogersville Shale is a part of a petroleum system in the fault-bounded Rome Trough of eastern Kentucky and West Virginia that can only be produced with high-volume hydraulic fracturing. In Kentucky, the Rogersville Shale ranges in depth from ~1,800 m to ~3,700 m below the surface with the crystalline basement being ~1,000 m lower than the formation's base. Microseismic data were collected by the Kentucky Geological Survey as part of a three year project designed to observe background seismicity in the Rome Trough with a focus on areas of recently completed and planned oil and gas test wells in the Rogersville Shale, and clusters of wastewater injection wells. Thirteen broadband seismic stations were deployed between June, 2015 and June, 2016, and two more were deployed in 2017. Existing University of Kentucky and CEUSN seismic stations contributed to the monitoring, yielding an average station spacing of 25 km in the project area. A complete analysis of the project from June, 2015 through June, 2018 including event locations and magnitudes will be presented.

Preferred Platform: Oral Presentation

Student Presenter: N

Stress drop investigation of induced earthquakes in Alberta using Empirical Green's function method

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The high-frequency energy of ground motions is partly controlled by an important source parameter referred to as stress drop. We investigate stress drops of induced earthquakes in Alberta, Canada, linked to hydraulic fracturing, using the Empirical Green's function (EGF) method. The EGF method is an efficient technique to obtain the source spectra of an earthquake. It removes the path and site components of a larger event by taking the spectral ratio of the target event to that of a smaller, collocated, event (an empirical EGF). We use cross-correlation to find suitable small earthquakes to use as empirical EGFs for selected target events. The multitaper method is used to define the spectra for the target and EGF events. Spectral division results in the source spectra of the target events, which can then be inverted, assuming a Brune (omega-squared) source model, to obtain the corner frequency of the target event. The corner frequency is an inverse measure of stress drop. Results from this study will be used to compare source properties of induced events in western Canada to those in other regions. The results will also be used to compare EGF stress drop estimates with stress parameter values inferred from stochastic models of high-frequency ground motions.

Preferred Platform: Oral Presentation

Student Presenter: Y

Induced seismicity impact on housing prices in Oklahoma City: A type of indirect earthquake loss?

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This study seeks to identify the economic impacts associated with earthquakes caused by unconventional oil and gas production and wastewater injection activities. Our identification strategy consists of linking geographically proximate housing values to induced earthquake activities within Oklahoma County, Oklahoma. Using both seismic (i.e., PGV) and self-reported (i.e., USGS DYFI) ground motion intensity measures, we provide robust evidence that seismic events are negatively impacting property values, which are located in relative close proximity to an earthquake's epicenter. We argue that induced earthquakes are endogenous to housing values due to the predetermined siting of injection wells into select regions within the metropolitan statistical area. Based on these observations, we take care to control for the impact of oil & gas drilling/wastewater disposal activity on housing prices and separate these out from the earthquake ground motion impact. Using an instrumental variables approach based on number of earthquakes with $PGV \geq 0.5$ cm/sec and cumulative Community Decimal Index (based on DYFI reports) observations, our findings suggest that the cumulative effect of each additional earthquake generates, on average, a 2.9 to 2.4 percent reduction in housing values. Based on the reduction in prices, we estimate the total per-household costs associated with induced earthquakes in Oklahoma County are approximately \$3,628 to \$4,365. Taken together with the ~152, 500 housing transactions during the study time period, this suggest a total negative economic impact of induced earthquake activity of US\$544 to US\$666 million.

Preferred Platform: Oral Presentation

Student Presenter: N

A Review of Reservoir Monitoring and Reservoir-Triggered Seismicity in Canada

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Canada has four of the 20 largest water reservoirs in the World with 16 that are at least 75 m deep with a volume greater than 10^9 m^3 . Eleven of these are located in the Canadian Shield of Quebec and five in the Cordillera of British Columbia and Alberta. Six of these large reservoirs were associated with Reservoir-Triggered Seismicity (RTS) plus two other cases in smaller reservoirs in Quebec. This is a larger proportion (37%) than for worldwide dams higher than 90 m (10%). All RTS cases were located in the Canadian Shield of Quebec, an area that is weakly seismically active. RTS was of small to moderate magnitude (the largest event was Nuttli magnitude MN 4.1). Based on the known cases of RTS and of those that had no associated seismicity, some conclusions can be drawn. Before the mid 1970s, many potential triggered earthquakes could have been below the detection threshold (generally magnitude 3.5) offered by the Canadian National Seismograph Network at the time. The weight of the reservoirs does not appear to be the main factor to trigger RTS: two of the largest reservoirs by volume do not have any associated activity. In all RTS cases, it is almost impossible to relate the activity to some specific fault characteristics. In some RTS cases, filling was not completed when the RTS started. For these cases, it is not easy to distinguish between a rapid-response (the weight of the reservoir increases the pore fluid pressures at depth) versus the delayed-type where the pore-fluid pressure diffusion leads to reactivation of the fault. For the majority of RTS cases, however, a delayed-response type appears more likely, i.e, activity started shortly after the initial impoundment, continued for many months, sometimes in swarms, and finally stopped after a few years.

Preferred Platform: Oral Presentation

Student Presenter: N

Poroelectric stress change and fault slip induced by fluid injection

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Solid matrix stress and pore pressure changes due to fluid injection are key factors for inducing earthquakes on pre-existing faults. In this study, we first present poroelectric stress modeling results for multi-stage hydraulic fracturing and wastewater disposal scenarios, with applications to induced earthquakes near Fox Creek, Alberta and Cushing, Oklahoma, respectively. In both cases, the shear and normal stresses critically influence the Coulomb stress regimes and consequently seismicity distribution, despite their relative amplitudes to the pore pressure increase in the two types of injection scenarios. We further introduce the poroelectric stress changes as perturbations to a nearby, pre-existing fault governed by the rate-state friction constitutive law to simulate conditions for inducing aseismic and seismic slip. In the application to the December 2013 earthquake sequence near Fox Creek, we find that fault slip rate evolves in a manner similar to the onset of seismicity. For a modeled 15-stage HF of ~ 10 days, fault slip rate starts to accelerate after 3 days of fracking, which temporally coincides with the onset of seismicity. Slip rate continues to evolve and remains high (but below seismic threshold) for several weeks, which may explain the continued seismicity after shut-in. We further investigate fault slip response under two hypothetical perturbation scenarios. In scenario #1 when perturbation instantaneously returns to zero at shut-in, fault slip rate quickly decreases to the pre-fracking level. In a more aggressive scenario #2 when perturbation is removed just a few hours after the slip rate starts to accelerate (fracking is terminated prematurely), only aseismic slip is observed in the model. Our results suggest the design of HF stages and flow-back strategy, either allowing perturbations to passively dissipate or actively reducing to the pre-fracking level, is critical for inducing seismic versus aseismic slip on a pre-existing fault.

Preferred Platform: Oral Presentation

Student Presenter: N

Performance and input parameter evaluation of the USGS one-year seismic hazard forecasts

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In 2018, the USGS National Seismic Hazard Model Project (NSHMP) will produce the third annual one-year induced and tectonic seismic hazard forecast. The 2018 forecast predicted that hazard remains high in regions with significant induced seismicity relative to the 2014 long-term tectonic hazard model. The large increase in seismicity in the central and eastern US (CEUS) since 2009, primarily a result of increased wastewater injection related to oil and gas production, provides a valuable ground motion dataset for evaluating the performance and input parameters of the one-year hazard forecasts. We evaluate the performance of the forecast by comparing the forecasted ground motions with observed ground motions recorded in 2016 and 2017. Given the uncertainty in ground motion models (GMMs) and hazard curves we find that the one-year models accurately forecast the ground motions experienced in most regions (central Oklahoma, Raton Basin) during 2016 and 2017. In other regions (Dallas, Arkansas, Charleston) the hazard forecast over-predicted ground shaking. The new ground motion observations also provide us an opportunity to test the performance of GMMs used in the forecast. GMM selection introduces a significant source of uncertainty in probabilistic hazard models. We evaluate, rank and weight over 50 CEUS and western US GMMs using two well-established probabilistic methods (log likelihood (LLH), and multivariate LLH (MLLH)). We compute ground motion residuals for peak ground acceleration (PGA) and 1 second pseudospectral acceleration (PSA1.0) using GMMs recently implemented in the USGS NSHMP software system (nshmp-haz, available at <https://github.com/usgs/nshmp-haz>). LLH and MLLH GMM rankings are consistent and indicate that, in general, newer GMMs with lower standard deviations perform better than older GMMs. Results from these studies allow us to select appropriate metrics for evaluation of earthquake hazard models.

Preferred Platform: Oral Presentation

Student Presenter: Research Geophysicist

Seismic hazard forecasts that consider induced earthquakes

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Due to their transitory nature, induced earthquakes are considered unsuitable for long-term seismic hazard applications like building codes. The potential hazard from these events can be significant, however, and the USGS has developed models to try to forecast this hazard. The new models are based on the USGS National Seismic Hazard Models (NSHM), but they differ in their short-term focus: forecasts are valid for one calendar year, and they are primarily based on the previous year's seismicity. Patterns suggest that induced seismicity can respond rapidly to reductions in fluid injection (including hazard-mitigation efforts) or shifting trends in hydrocarbon production; the short-term models are designed to cope with such changes. Other differences from the NSHM include alternative recurrence parameters, maximum magnitudes, and ground motion models. We have identified 21 zones of induced activity in the CEUS from the literature and local expertise. The new models use a declustered catalog, consistent with the NSHM. The model for year 2016, based primarily on 2015 seismicity, was considered successful for Oklahoma because several large earthquakes occurred there in 2016 (Fairview, Pawnee, Cushing) that were consistent with the forecast. Models for 2017 and 2018 have shown more complex results for Oklahoma. Seismicity has recently diminished overall, but this trend is not fully mirrored in the declustered catalog. This may be partly due to complicated interactions between the declustering windows and the short catalog; declustering time windows range in duration from several months to almost one year for the largest Oklahoma earthquakes. This has called into question the use of the declustered catalog, and we are considering other approaches, including using the full catalog. Regardless, hazard remains high in some areas compared to pre-injection levels. I will describe the methodology, some results, and some considerations for future modeling.

Preferred Platform: Oral Presentation

Student Presenter: N

Tidal loading stress in the Bay of Fundy: is there a risk of induced seismicity?

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The gravitational loading of the Earth's surface by the large marine tides in the Bay of Fundy generates a concentrated periodic stress field that is an order of magnitude larger than the global-scale stress field due to the Earth tides. The locally-distributed stress is conducive to the migration of excess pore-pressure into areas of unstable faults. While recent studies on correlations between the tidal stress tensor and focal mechanisms inferred from concomitant earthquakes have underscored the role of ocean tide loading, the question remains open whether tidally-induced excess pore-pressure can trigger tremors or earthquakes in the Bay of Fundy (or Gulf of Maine). This very question was directly addressed only several decades ago by Beaumont and Quinlan (1977); however, ever since, much advances have been achieved in every aspects of the oceanographic and geophysical dynamics of the Bay of Fundy, in parallel with work elsewhere on precisely mapping the displacement field of loaded coastal regions via GNSS data. Here, I examine the loading stress contribution of the predominant tidal constituent M2 (period 12 h 25 m) about which the Bay of Fundy and Gulf of Maine marine system resonates. In assessing the characteristics of this semi-diurnal loading stress field, particular attention is paid to: 1) the permeable nature of the system's water-rock interface; and 2) any increase or decrease of the system's resonant frequency. Regarding the latter, the amplitude of the M2 marine tides in the Bay/Gulf system is currently varying due to poorly-determined causes; thus, the apparent variations of the amplitude, whether caused by some tectonic process, modification of the system's geometry, energy harnessing via operating current turbines, or by global warming, are considered.

Preferred Platform: Oral Presentation

Student Presenter: N

Hydraulic Fracturing Volume is Associated with Induced Earthquake Productivity in the Duvernay Play

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A sharp increase in the frequency of earthquakes near Fox Creek, Alberta began in December 2013 in response to hydraulic fracturing. Using a hydraulic fracturing database, we explore relationships between injection parameters and seismicity response. We show that induced earthquakes are associated with completions that used larger injection volumes (10^{4-5} m³) and that seismic productivity scales linearly with injection volume. Injection pressure and rate have an insignificant association with seismic response. Further findings suggest that geological factors play a prominent role in seismic productivity, as evidenced by spatial correlations. Together, volume and geological factors account for ~96% of the variability in the induced earthquake rate near Fox Creek. This result is quantified by a seismogenic-index modified frequency-magnitude distribution, providing a framework to forecast induced seismicity.

Preferred Platform: Oral Presentation

Student Presenter: N

Aeromagnetic data image numerous potentially seismogenic faults in Oklahoma

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We use new aeromagnetic data to image potentially seismogenic faults in the crystalline basement of north-central Oklahoma. Contacts between rocks with different magnetic properties, which may represent faults, are determined using a horizontal gradient magnitude peak method. Of these contacts, those which are more linear and do not appear to be intrusion boundaries are interpreted as possible faults. Numerous earthquake sequences have occurred in Oklahoma since 2009; we find that many are aligned with magnetic contacts, supporting an interpretation of pre-existing faults. However, not all earthquake sequences occur along delineated contacts. For some sequences the faults appear to offset complex geologic configurations that don't generate simple horizontal gradient peaks; in these areas other anomaly variations are visible. Other faults might not generate offsets between rocks with different magnetic properties. The magnetic contacts show better correspondence with the earthquake sequences than with previously mapped faults. This is probably because the fault maps are based on data describing the mostly nonmagnetic sedimentary cover, and the earthquakes occur in the basement. The dominant structural grain of the basement strikes N50E-N70E, notably different from that of the sedimentary cover. These observations strongly suggest there are significant structural differences between the Paleozoic cover and underlying Precambrian crystalline basement. These differences are probably due to the more complex tectonic history of the basement, and indicate the importance of deeper geophysical imaging in the intraplate environment. Furthermore, the dominant structural grain of the basement overlaps the favored orientation for fault slip in the modern stress regime (N40E-N60E and N60W-N80W). This may be a contributing factor to the extensive amount of induced seismicity in north-central Oklahoma.

Preferred Platform: Oral Presentation

Student Presenter: N

Faults and non-double-couple components for induced earthquakes

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Focal mechanisms of induced earthquakes reflect anthropogenic contributions to the pre-existing geological features and fault slippages. In this paper, we examine the fault-related (double-couple, DC) and possibly fluid-related (non-double-couple, non-DC) mechanisms of induced earthquakes at a regional scale (M2-6). We systematically compare the well-resolved focal mechanisms of 33 shallow events in the Western Canada Sedimentary Basin, among which 12 were induced by hydraulic fracturing and one by secondary recovery. Regardless of their nature, most of the seismicity is dominated by strike-slip/thrust faulting regimes, whereas limited (but consistent) non-DC components are obtained from the hydraulic-fracturing induced seismicity in central Alberta. We interpret the persistent compensated-linear-vector-dipole (CLVD) components (M2.1-3.8) as reflecting 1) fracture growth during hydraulic-fracturing stimulation and/or 2) co-slipping of the dextral transensional faults. We further expand the moment tensor decomposition analysis to four representative classes of induced seismicity globally and find that the overall contribution of non-DC components is largely comparable between induced and tectonic earthquakes.

Preferred Platform: Oral Presentation

Student Presenter: Y

A tale of two clusters: differentiating induced and natural seismicity in southern Ontario using waveform correlation template detection

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A cluster of small shallow seismic events near Leamington, on the north shore of Lake Erie, is now suspected to be industry-related. This is based on spatiotemporal proximity to active wastewater disposal wells. Nine events were detected by conventional means, with Nuttli magnitude $1.5 \leq MN \leq 3.0$, in the period 2002–2017. A second cluster of small shallow earthquakes under Lake Huron is receiving attention as part of seismic monitoring relating to the Bruce Nuclear site. Eight events with $1.2 \leq MN \leq 2.5$ have been detected in the same period. These events are offshore, far from any industrial activity. Both clusters share some salient characteristics. The geological setting consists of Paleozoic sedimentary rocks overlying a crystalline Precambrian basement, 1300 m deep near Leamington and 600 m deep near the Bruce Nuclear site. All events are believed to be shallow because the largest in each cluster have well developed crustal Rayleigh phases. In both areas the magnitude of completeness is close to $MN = 2.0$ since the Polaris upgrades of 2002, but stations are too far away to obtain estimates of depth from direct phases. Barring deployment of narrow-aperture seismograph networks to study these clusters more closely, we need to make better use of data already available. Multi-channel cross-correlation template detectors provide a means to detect microseismic events, below the network magnitude of completeness. These events are assigned magnitudes relative to the template events. With enough detections, it becomes possible to estimate recurrence parameters and assess aftershock decay rates. It has been hypothesized that an anomalously low decay rate or an absence of apparent decay is an indicator of anthropogenic forcing. This study investigates whether temporal patterns of microseismic activity can help to differentiate induced and natural seismicity.

Preferred Platform: Poster Presentation

Student Presenter: N

**CELLULAR SEISMOLOGY PREDICTABILITY AS A MEASURE OF ASSOCIATION
BETWEEN WASTEWATER INJECTION WELLS AND EARTHQUAKES: THE
STORY BEHIND THE STORY**

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A modified version of “Cellular Seismology” (CS, e.g., Kafka, 2007; Chambless and Kafka, 2017) is used to explore the interrelated effects of space and time on the potential for well injection to induce earthquakes. Originally developed to test hypotheses regarding the extent to which past earthquakes delineate zones where future earthquakes are likely to occur, CS is repurposed here for application to the study of induced seismicity. The modified CS method, referred to as MCS, involves replacing the past earthquake catalog of CS with a catalog of injection well locations. We use “CS predictability” (CSP) as an operational definition of the extent to which injection wells are associated with induced earthquakes. In the original version of CS, CSP was defined as the percentage of recent earthquakes that occurred near past earthquakes. Here we define CSP as the percentage of earthquakes in a given catalog of post-injection earthquakes that occurred near injection wells. This study explores MCS/CSP as a way of quantifying how the spatial distribution of possibly induced earthquakes in regions around injection wells varies with time. Statistical tests combined with this repurposed CS provide a window into the spatiotemporal patterns of injection well-induced seismicity. Using MCS, we test hypotheses regarding the extent to which injection well locations delineate zones where earthquakes are likely to be induced and also explore how far from those wells (in both space and time) the injection activity influences the potential for inducing earthquakes. We find evidence that the potential for inducing earthquakes extends to about 15 km from the injection wells, although earthquakes are most likely to be between 2-3 km from any given well and second most likely to be between 9-10 km from any given well. We also find evidence that the number of earthquakes associated with wells decays at a rate of about 1% per year in the years following well injection activity.

Preferred Platform: Poster Presentation

Student Presenter: N

**Sharp increase seismicity induced by hydraulic fracturing in the Junlian-Gongxian,
Sichuan Basin of China**

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Most induced seismicity is linked to deep disposal of wastewater in the mid-continent of the United States. In contrast, In western Canada, hydraulic fracturing activities have induced the majority of earthquakes. For example, an event of MW 3.9 was induced by hydraulic fracturing several weeks after well completion; this earthquake was apparently due to reactivation of a nearby fault that appears to extend from the production horizon into crystalline basement near Crooked Lake, Alberta, Canada (Bao and Eaton, 2016). In the Sichuan Basin of China, the increase in earthquake activity starting in 2014 appears to be similar to that in western Canada in terms of its relationship to hydraulic fracturing activities that have begun only recently. In the Junlian-Gongxian, more than 80 earthquakes with $ML \geq 3$ occurred in the 4 years from 2014 through 2017 within a production area with a diameter of about 20 km. In the same area, the average rate was 1 earthquake detected every two years from 1970 to 2013. Similarly, four $ML \geq 4$ earthquakes have occurred within ~5km of hydraulic fracturing operations that took place from the 12th to 19th Jan, 2017. The largest event (MW 4.7) occurred on 28 January 2017, 9 days after the cessation of nearby hydraulic fracturing, as reported by Lei et al. (2017). To improve our understanding of this new seismicity, a mobile network of 21 temporary stations has been installed to lower the magnitude threshold of completeness substantially so as to produce a more comprehensive catalog. We then utilized spatial and temporal filters to identify hydraulic fracturing wells that may be associated with earthquakes (e.g., Weingarten et al., 2015). The relationship of this smaller-magnitude seismicity to well-completion operations is additional evidence that the new seismicity in this region is induced. Acknowledgments This research supported by the China Earthquake Science Experiment (CESE) grant 2016CESE0101.

Preferred Platform: Poster Presentation

Student Presenter: N

Effects of Injection-related Dynamic Poroelasticity in Cardium Formation in West-Central Alberta

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The Upper Cretaceous Cardium Formation is the reservoir for a low-permeability “tight oil” play in the Pembina region of west-central Alberta. Beginning in 2010, more than 500 horizontal wells have been completed in this play using multistage hydraulic fracture treatments. The Cardium tight oil play is the subject of our study because of concerns of the potential hazard of triggered seismicity in a region with sensitive surface infrastructure. The Cardium Formation comprises stacked coarsening-upward shallow marine shaly sand allomembers with low porosity and permeability. The formation is conformably overlain and underlain by thick shale successions of the Wapiabi and Blackstone Formations, respectively. Horizontal production wells are landed in shaly sandstones of the uppermost Raven River allomember of the Cardium and the pay zone has an average thickness of 15 meters. We used COMSOL Multiphysics software to build a 3D fully coupled model of pore pressure diffusion and solid deformation due to fluid injection during hydraulic fracture treatments. Well reports and geophysical wireline logs provide injection rate and volume, elastic and petrophysical properties of the rocks. These data are incorporated into the finite-element model to estimate pressure and poroelastic stress changes. Despite high cumulative rate and volume of injection, no evidence of induced seismicity has been recorded in the area. This corresponds to our preliminary simulation results showing that pore pressure perturbation is restricted within the Cardium Formation. Pore pressure diffusion is inhibited because the injection layer is sandwiched between two thick layers of shale with lower porosity and permeability. Overall, stratigraphic architecture exerts the primary control on confining pore pressure changes to the Cardium Formation; however, injection duration, rate, and spatiotemporal spacing between stages can locally affect pressure and poroelastic stress variations.

Preferred Platform: Poster Presentation

Student Presenter: Y

Empirical Ground Motion Characterization of Induced Seismicity in Alberta and Oklahoma

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Over the last decade instances of induced seismic activity resulting from waste water injection and hydraulic fracture treatments have increased significantly both in rate and maximum magnitude of observed events. Evaluation of the induced-seismicity hazard requires development of appropriate ground-motion prediction equations (GMPEs). We use a generalized inversion to solve for regional source, attenuation and site parameters to define region-specific GMPEs from induced ground motion observations in Alberta and Oklahoma following the method of Atkinson et al. (2015 BSSA). The Alberta database is compiled from over 200 small to moderate seismic events (M 1 to 4.2) recorded at ~ 50 regional stations (distances from 30 to 500 km). We use over 13,000 small to moderate seismic events (M 1 to 5.8) recorded at ~ 1600 seismic stations (distances from 1 to 750 km) in Oklahoma. Magnitude scaling and geometric spreading functions are removed from observed ground motions and are inverted for stress parameter, regional anelastic attenuation terms and site amplification. Resolving these parameters allows for the derivation of regionally-calibrated GMPEs that can be used to compare ground motion observations between waste water injection (Oklahoma) and hydraulic fracture induced events (Alberta), and further compare induced observations with ground motions resulting from natural sources (California, NGAWest2). The derived GMPEs have applications for the evaluation of hazards from induced seismicity and can be used to track amplitudes across the regions in real time, which is useful for ground-motion-based alerting systems and traffic light protocols.

Preferred Platform: Poster Presentation

Student Presenter: Y

Seismic source characterization of an induced-seismicity sequence associated with a hydraulic-fracturing stimulation in a Duvernay shale play

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The recent increase in the development of the Duvernay shale play, located in the Fox Creek area in central Alberta, Canada, has been closely associated with a sharp increase of seismic activity observed in the same area since 2013. This has been linked with the hydraulic fracturing stimulations required to increase the productivity of low-permeability reservoirs, making necessary the implementation of dense and close seismic monitoring during and after these stimulations to better understand the mechanisms that induce such anomalous seismicity. This manuscript presents a case study where a multi-stage hydraulic-fracturing stimulation in the Duvernay-Fox Creek shale was monitored with a near-surface array composed by multi-component short-period geophones and broadband seismometers. We implemented an array-processing sequence to automatically detect microseismic events and calculate their hypocentre location, seismic moment, moment magnitude, source radius, and radiated energy. The focal mechanism of the strongest seismic events, also detected by a regional seismological network and with reported magnitudes between 1.5 and 3.6, clearly delineate the fault-reactivation sequences that originated such events. Finally, we measured the coda length of all the detected events and obtained a trilinear coda-magnitude scale for magnitude estimation of seismic events, validated for a magnitude range between -0.5 and 3.6.

Preferred Platform: Poster Presentation

Student Presenter: Y

**CGU_S_03: The structure and dynamics of western North America:
Setting the stage for CCArray and EON-ROSE**

Conveners: Claire Currie¹, Pascal Audet², David Eaton³, Eugene Humphreys⁴, Jeffrey Gu⁵

Co-chairs: Claire Currie, Pascal Audet, David Eaton, Eugene Humphreys

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Wyoming craton growth by Shatsky conjugate under-accretion at ~65 Ma

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The Wyoming lithosphere is odd: (1) Laramide thrusting occurred deep within the continent. (2) Wyoming elevated 1-2 km (a major change in craton buoyancy). (3) Seismically high-velocity mantle extends ~270 km beneath the craton. (4) Post-Laramide xenoliths from below ~150 km are only ~140 Ma in age (pre-Laramide xenoliths are Archean). But just when and where it is needed, the Shatsky conjugate oceanic plateau is thought to arrive to Wyoming, being transported on the flat-subducting Farallon slab. We account for the above observations with flat-slab basal tractions driving Laramide thrusting and erosion of basal continent, with the oceanic plateau being abandoned beneath Wyoming. We cannot think of another reasonable explanation. But the plateau's ocean crust is absent: an eclogitic crust would offset the required buoyancy of the depleted mantle, and a basaltic crust would be obvious in receiver functions. The ocean plateau crust was not lost during subduction beneath California starting ~90 Ma. The western Colorado Plateau elevated ~1 km when the Shatsky conjugate arrived 80-70 Ma, implying a basaltic (buoyant) oceanic plateau crust. In contrast, a strong and localized focus of rapid subsidence propagated east across the Rocky Mts ~85-70 Ma, suggesting the oceanic crust was transforming to eclogite. Anomalous subsidence ended ~75-70 Ma and the region rebounded, suggesting loss of an eclogitic ocean crust. The Colorado Mineral Belt (rare Laramide magmatism) initiated ~75 Ma along the southern margin of both the region of subsidence and the location of the Shatsky conjugate at 75 Ma, suggesting it represents a tear in the Farallon slab through which the eclogizing ocean crust escaped. The slab-stacking hypothesis for craton creation is similar, with oceanic crust and lithosphere of properties similar to the Shatsky conjugate underthrusting the craton. In this model, the oceanic crust needs to be removed. The Wyoming example may suggest how this happened.

Preferred Platform: Oral Presentation

Student Presenter: N

Controls on continental lithosphere deformation: Numerical modeling of Farallon flat-slab subduction and the Laramide Orogeny

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The Late Cretaceous Laramide Orogeny (~75 Ma to ~40 Ma) was a period of thick-skinned lithosphere shortening and surface uplift in the western United States that occurred more than 700 km inboard of the Farallon Plate subduction zone. The driving forces that produced Laramide deformation so far inboard of the plate margin remain enigmatic but are widely believed to be associated with flat-slab subduction. Here we use 2D thermal-mechanical models using the SOPALE code to study the dynamics of Farallon flat-slab subduction and deformation of the continental lithosphere. Models correspond to a geological time of ~90 Ma to ~50 Ma, during which an oceanic plateau (conjugate Shatsky Rise) is inferred to have subducted beneath western North America, initiating flat-slab subduction. We test the idea that interactions between the flat-slab and the presence of a pre-existing continental weak zone resulted in inboard deformation. Models examine the influence of the structure and rheology of the weak zone on triggering lithosphere deformation, focusing on three factors: (1) continental mantle lithosphere strength (approximating conditions from wet olivine to dry olivine), (2) lower crustal strength, and (3) width of the weak zone (500 km and 700 km). Models show that the development of thick-skinned deformation and shortening require a relatively weak continental lithosphere and is enhanced by a weak crust and wide weak zone. Future work will focus on how stress transfer from the flat-slab induces continental deformation and on the topographic record of flat-slab subduction and shortening.

Preferred Platform: Oral Presentation

Student Presenter: Y

Evidence for hydration and its role in dynamics of the western U.S. Cordillera

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The relative importance of thermal variations and volatile state in dynamics of the lithosphere remains poorly understood. Temperature and hydration state both can significantly influence buoyancy, flow strength, melt dynamics and tectonism, but they also perturb the seismic and electrical properties that we most commonly image in ways that make the interpretation of physical state somewhat ambiguous. EarthScope's USArray has precipitated several innovative approaches to imaging and characterization of physical state in the crust and lithosphere, however, and some of these afford hope that this tough nut can be cracked. For example, a new mineral physics approach to estimating temperature at the Moho from Pn tomographic data vastly reduces the uncertainty in temperatures at mantle depths. Joint inversion of seismic receiver functions and gravity improves characterization of the seismic velocity ratio, v_P/v_S , of the crust, and investigation of a multi-layered crust suggests bulk-crustal v_P/v_S variations are dominated by heterogeneity of the lower crust. New mineral physics modeling indicates that crustal v_P/v_S (which is very sensitive to quartz abundance) may have implications for the crustal hydration history. Combining these observations in models of (relatively low resolution) measurements of lithospheric flexural rigidity suggests that stable versus deforming lithosphere is defined largely by the hydration state of the uppermost mantle, with a likely assist from partial melting favored by reduction of the melt temperature that accompanies hydration. Discrepancies between surface heat flow and Moho temperature moreover suggest a role for hydration transport and reaction enthalpy in thermal transfer through the lithosphere. Taken together, these disparate clues suggest a robust role for volatile chemistry in dynamics and elevation of the western U.S. Cordillera.

Preferred Platform: Oral Presentation

Student Presenter: N

Channel flow and Moho structure across the backarc-craton transition in the northern U.S. Cordillera

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The western edge of the North American craton (Laurentia) in southern Canada and northern U.S is marked by a profound change in lithospheric thickness from 100 km beneath the Cordillera to 200 km beneath the craton. The tectonic environment of the southern Canadian Cordillera extends southward to the Lewis and Clark shear zone (LCSZ). Transportable Array (TA) broadband data from 49 stations were used to compute receiver functions (RFs) using iterative deconvolution method. H-k stacking and a Gaussian-weighted common-conversion-point stacking technique were also used to obtain estimates of crustal thickness and to construct a set of east-west RF profiles. Our observations reveal a uniformly flat and shallow Moho in the backarc region of southern Canada and north of LCSZ interpreted as a young feature that was produced by lower-crustal channel flow. Along with other geological and geophysical data, the observations suggest progressive eastward development of a young Moho. South of the LCSZ, the juxtaposition of weaker terranes has created more extensive thermal reset of the sub-Cordilleran Moho.

Preferred Platform: Oral Presentation

Student Presenter: Y

Bulldozing of continental mantle lithosphere during flat-slab subduction

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Eastern-Pacific flat-slab subduction below South America has stopped or reduced arc magmatism, and has caused upper-plate deformation to migrate inland. In the western U.S., (arc) magmatism largely ceased above the Laramide flat slab, and Laramide uplifts, basins, and folds related to Farallon flat-slab subduction formed 1000 km inboard of the plate margin, well ahead of the inferred maximum extent of the flat slab. We have developed thermal-mechanical numerical models of flat-slab subduction to understand and explain these observations. The models are designed after Farallon-plate subduction. In our models, the flattening of the Farallon plate initiated with subduction of the buoyant conjugate Shatsky Rise and was aided by breakoff of the dense frontal slab. This created a gap in the subducted Farallon slab, which is imaged tomographically. As flat-slab subduction progressed, the advancing slab scraped off the lower ~20-50 km of continental lithosphere, leaving no asthenosphere between the slab and overriding plate. The displaced material accumulated in a bulldozed keel ahead of the slab owing to its compositional buoyancy. This ended arc-magmatism rather than causing an inboard migration. Flat-slab removal left a step in the upper-plate lithosphere and/or bulldozed keels at the base of the overriding plate, and re-established the asthenospheric wedge and melting. We compare these model predictions with patterns of magmatism and seismic tomographic images of the western US and South America.

Preferred Platform: Oral Presentation

Student Presenter: N

Temperature and water content of the upper mantle in the southwestern Canada

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Geophysical observations indicate a significant lateral variation in mantle properties between Cordillera and North American Craton in southwestern Canada. Compared to the Craton, the Cordillera has lower seismic velocity, higher surface heat flow, lower electrical resistivity, and lower effective elastic thickness. This suggests a hot, thin lithosphere for the Cordillera and cold, thick lithosphere for the Craton. Previous studies have argued that the thin Cordilleran lithosphere is maintained by vigorous convection of a low viscosity and hydrated mantle, whereas Cratonic lithosphere is dry and resistant to thinning. We use two independent data sets, seismic shear-wave (V_s) tomography (Models NA07 and SL2013NA) and magnetotelluric (MT) observations, to examine temperature, composition and water content at 70-250 km depth. The V_s analysis requires a few assumptions, including mantle composition (via *Perple_X*), grain size, and attenuation. The effects of attenuation become significant at temperatures higher than 900 °C. The MT analysis is based on empirical models of the electrical resistivity of hydrous olivine as a function of temperature and water content. The joint V_s -MT analysis suggests that the Cordillera mantle has an average temperature of 1100-1300 °C and water content of 2500-5000 ppm H/Si. In contrast, the Craton mantle is 900-1100 °C and water content below 1000 ppm H/Si. There are consistent with the hypothesis of a warm, wet Cordillera mantle and cold, dry Craton mantle. The boundary between Cordillera and Craton is delineated by a high lateral gradient in V_s and electrical resistivity

Preferred Platform: Oral Presentation

Student Presenter: Y

Constraints on crustal structure and seismicity surrounding the Beaufort Sea, western Canadian Arctic, from broadband seismic data

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The formation and evolution of the lithosphere in the western Canadian Arctic represent a long-standing tectonic puzzle. The eastern Beaufort Sea margin juxtaposes young (150 Ma) Arctic Ocean lithosphere with Paleo-Proterozoic continental lithosphere of the Canadian Shield underlying Banks Island, over 200 km. The southern Beaufort Sea Mackenzie Delta margin represents a well-developed fold and thrust belt of Cretaceous to present age, but has only been recently recognized as likely active. A concentration of poorly constrained earthquakes within the Beaufort Sea are interpreted as due to flexure of the oceanic crust in response to margin thrusting or loading of thick Mackenzie Delta sediments. We use data from new land broadband seismic networks to investigate crustal structure and seismicity around the Beaufort Sea. Preliminary results from ambient seismic noise and receiver function analyses indicate a ~30 km deep Moho beneath the Beaufort Sea and Banks Island. We examine focal depths of selected Beaufort Sea earthquakes using teleseismic P-pP times and find focal depths of ~35 km. These results suggest that earthquakes occur on reactivated passive margin structures, possibly triggered by flexural loading.

Preferred Platform: Poster Presentation

Student Presenter: N

Mantle structure and dynamics at the Cordillera-craton transition in western Canada

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The Canadian Cordillera is a Phanerozoic orogen formed through plate convergence and subduction at the western margin of the North American craton. Seismic tomography indicates that the Cordillera mantle has anomalously low seismic velocities, whereas the Craton mantle has high velocities. These primarily reflect differences in mantle temperatures, such that the Cordillera has a hot, thin (~60 km) lithosphere and the Craton lithosphere is cooler and thicker (200 km). The change from low to high velocity occurs over a lateral distance of 100 km, implying a dramatic change in lithosphere thickness at the Cordillera-Craton boundary. The geometry of the boundary varies from subvertical-to-east-dipping north of 54N to west-dipping in the south. In this study, we explore the factors that contribute to the present-day structure of the Cordillera-Craton boundary using two-dimensional thermal-mechanical numerical models. Model results are converted to seismic velocity structure using theoretical and laboratory-based constraints on elastic parameters. The models demonstrate that the observed gradient in lithosphere thickness can persist for 50 Ma only if the craton mantle is both dry and chemically depleted, and thus is rheologically strong and buoyant. They also show that the Cordillera-craton boundary is not stagnant and its geometry can be modified by edge-driven convection, internal gravitational instabilities, shearing by regional mantle flow, and continental shortening. These effects are enhanced if the craton lithosphere is internally layered with a weaker region in the upper 100-150 km. The observed latitudinal geometry variations may reflect differences in the timing of craton deformation and the direction of regional mantle flow, possibly related to the present-day plate boundary processes to the west.

Preferred Platform: Poster Presentation

Student Presenter: N

CGU_S_04: Solid Earth Geophysics: All for one and one for all!

Conveners: Phil McCausland¹, Claire Currie², Fiona Darbyshire³

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Modelling porosity melt bands in a mid-ocean ridge corner flow

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When a partial melt system is subjected to shear, an instability can occur in which porosity segregates into bands whose orientation is controlled by the stress field. It has been suggested that these bands may act as high permeability conduits for melt to be transported to the ridge axis, might be significant in lowering the effective viscosity in regions of the upper mantle and might have effects on seismic anisotropy and electrical resistivity. If the melt is buoyant relative to the background material, porosity waves can occur. In this contribution, we model the evolution of porosity bands through a mid-ocean ridge corner flow. We show that bands may only be of sufficient amplitude to significantly channel melt if the mantle bulk viscosity is low and the initial porosity heterogeneity is large. We also show that the orientation is generally not optimal for channeling melt towards the ridge axis but would instead in most cases channel it towards the base of the plate.

Preferred Platform: Oral Presentation

Student Presenter: no

HERB-SE: A Highly-Economical Rotating Base (Second Edition) Platform for Testing Real-Time Station-Based Positioning, Accelerometer & Combined Streams

Joseph Henton, Dan Perera, Paul Collins, Andreas Rosenberger, Deg Hembroff, Ryan Key, Yuan Lu, Lisa Nykolaishen, Herb Dragert, Mark Caissy,

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High-rate low-latency Global Navigation Satellite System (GNSS) data are being utilized for real-time (RT) applications focused on disaster mitigation, including tsunami early warning. RT-GNSS complements other geophysical monitoring (i.e., accelerometer) networks to improve the robust assessment and reporting of hazards; and post-event simulation of RT-GNSS processing using past earthquakes has been well-demonstrated. However, in order to facilitate testing of distributed (on-site) analyses and integration with other local sensors, Natural Resources Canada's Canadian Geodetic Survey (CGS) has implemented real-time GNSS processing on a low power, Linux platform. Currently three RT-time positioning streams may be executed locally: precise point positioning (PPP) with integer ambiguity resolution and 'float' PPP (both using RT clock and orbit correction streams) as well as fully autonomous single point positioning using broadcast orbits. To test both RT-GNSS derived coordinate streams (rather than velocity) in a controlled experiment, a mechanical system is used to drive the GNSS antenna along a circular path while keeping its orientation direction fixed. A strong-motion accelerometer (SMA) located beneath (co-axial to) the GNSS antenna is operated simultaneously (Figure). RT-GNSS position streams and SMA observations are recorded independently in order to produce suitable data sets to evaluate algorithms to fuse GNSS and SMA data streams. The reliability (amplitude and period accuracy) and noise characteristics of the currently available (and, possibly, developmental) RT-GNSS streams can be further evaluated. Ultimately, given the tectonic setting of Canada's west coast, megathrust earthquakes (Mw8) will be the primary targets for immediate identification.

Preferred Platform: Oral Presentation

Student Presenter: N

Open science for Discovery and Scientific Progress Together: Software Curation and Citation in the Geodynamics Community

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As research grows increasingly computational, traditional scholarly publication has expanded to recognize that scientific software can be a scholarly contribution. This is especially important in solid earth geophysics, where research often uses specialized software developed by the scientists themselves. Properly curating scientific software promotes reproducibility, replication, discoverability, and accessibility of research, and provides credit to scientists who develop software. As part of its mission to promote good scientific software practices in solid earth geophysics, the Computational Infrastructure for Geodynamics (CIG) maintains a community repository of research software for geodynamics. CIG (geodynamics.org) originated in part from recognition of the tremendous effort required to develop and sustain high quality software developed by the scientific community for geophysics. An analysis of typical practices using scientific in the solid earth geophysics publications showed that developers typically request that scientists using their software acknowledge funding agencies, refer to manuals, cite one or more peer-reviewed publications, or some combination of these, but do not usually request direct citation of the software package itself. To enable software users to directly cite software, and to provide examples of how to cite and attribute software, we developed the “attribution builder for citation” (abc). The abc tool uses zenodo as an archive and to assign a unique identifier (DOI) for scientific software and follows guidelines established by groups such as FORCE11 and OntoSoft. CIG aspires to have all actively developed packages use zenodo and github integration to automate the archiving process and provide metadata integration whenever a new software release is issued. Remaining open issues include how to handle legacy software and multi-authored libraries, and how to assign different authorship roles.

Preferred Platform: Oral Presentation

Student Presenter: N

Might Earth's solid inner core contribute to a precessionally driven geodynamo?

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The consideration of nonlinear effects is responsible for reinvigorating the discussion regarding precession as a viable and alternative energy source for driving the geodynamo. Understandably attention has previously emphasized the core-mantle boundary, as precession is deemed responsible for the constantly applied strain that introduces instability through one of two mechanisms - i.e., an elliptical distortion of (previously) circular streamlines and/or a shearing of the centres of the streamlines. Motivated by a series of laboratory experiments with a precessing spheroidal inner boundary within a spherically contained, rotating fluid shell, in the present effort emphasis is directed towards the inner-core boundary and its potential for contributions towards a precessionally driven geodynamo. In part, this motivation is justified by the consistent observation of a significant nonlinear interaction between inertial waves during their free decay, that follows their precessionally driven excitation in the laboratory experiments. After a re-analysis of these modal interactions as transient manifestations of a precessionally driven instability, application to the geodynamo problem is considered - where a growing, slightly flattened inner core might contribute to instabilities in Earth's fluid outer core on persistent and/or transient timescales. Because thermal and/or compositional convection in Earth's fluid outer core leaves open prospects for additional or alternative means for driving the geodynamo, there is ample geophysical motivation to more clearly elucidate precessionally induced possibilities, and in particular here to draw attention to the potential role of Earth's solid inner core - a role that might, for example, be manifest in paleointensity records that have already been successfully employed to provide compelling evidence for a tidally driven elliptical instability resulting from a strain constantly applied to the core-mantle boundary.

Preferred Platform: Oral Presentation

Student Presenter: N

Exploring the Cascadia megathrust transition from locked to slow slip: implications on fluid pressure and shear zone development

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The deep seismogenic transition from a frictionally locked to steady sliding interface at subduction zones is thought to primarily reflect variations in fluid pressure and rheology along the megathrust, and is, in general, located offshore. The development of elevated fluid pressure within a seismic low-velocity layer (LVL) remains poorly constrained due to the scarcity of dense, continuous onshore-offshore broadband seismic arrays. We image the subducting Juan de Fuca oceanic plate in northern Cascadia using a combination of onshore-offshore teleseismic data and find that the data do not require the LVL to extend into the locked zone. Thickening of the LVL down dip where viscous creep dominates suggests that it represents the development of an increasingly thick and fluid-rich shear zone, enabled by fluid production in subducting oceanic crust. Further down dip, episodic tremor and slip events occur in a region inferred to have locally increased fluid pressures, in agreement with electrical resistivity structure and numerical models of fault slip.

Preferred Platform: Oral Presentation

Student Presenter: N

Elaborating Inverse Problems in Geodynamics using Machine Learning Algorithms

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In the past few decades, numerical models have been intensively used in many fields of sciences including mantle processes and geodynamics. Although numerical modeling studies are very useful in understanding and estimating the processes occurring at high mantle pressures and temperatures, their applications can be limited due to the higher degrees of nonlinearity of the mantle processes and the uncertainties in the thermoelastic mantle parameters. The application of numerical methods in solving inverse problems in mantle dynamics is also limited by the nonlinearity of the mantle processes and high dependence of the mantle parameters on pressure and temperature. In this study we employ supervised machine learning (SML) algorithms for estimating of the mantle properties with a focus on the impacts of the iron spin transition in ferropericlase and perovskite in the lower mantle that may cause slab and plume stagnation at midmantle depths. Unlike traditional inverse theory methods like a Bayesian approach or iterative inverse approach by which the extraction of the mantle parameters such as viscosity or thermal conductivity is not straightforward, machine learning techniques seem to be powerful approaches for elaborating nonlinear inverse problems. As the complexity of the problem increases, deep learning and neural networks may be required for estimating of the thermoelastic properties of mantle and chemical anomalies.

Preferred Platform: Oral Presentation

Student Presenter: N

Enhanced Interpretative Ability of 3D UAV-borne Magnetic Surveys

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Recent advancements in geophysical exploration have been realized through reliably integrating unmanned aerial vehicle (UAV) platforms with light-weight, high-resolution magnetometer payloads. UAV-borne magnetic surveys provide a more desirable balance between the two end-members of resolution and coverage presently offered by airborne and terrestrial magnetic surveys. This balance is achieved as UAVs can safely fly closer to ground targets than manned airplanes, yet travel more efficiently than conventional terrain based measurements. Multi-rotor UAVs also provide the advantage of sensing the magnetic field at multiple flight elevations, allowing for the collection of 3D gradiometry datasets over baselines of 10's of metres. Magnetic gradiometry data is advantageous by providing better constrained depth estimates and shapes of subsurface targets. In July 2017, a UAV-borne magnetic survey was conducted using a GEM Systems Potassium Vapour Magnetometer (GSMP-35U). This survey took place within the Shebandowan Greenstone Belt, northwest of Thunder Bay, Ontario, Canada. Three grids (500m by 700m) of magnetic data were flown at elevations of 70m, 45m, and 35m above the ground with a DJI-S900 Multi-Rotor UAV. In total over 25 line-km of 3D magnetic data were flown at 25m line spacings with over 99% of the gathered UAV-borne data meeting industry standard (a fourth difference of ± 0.05 nT). The collected UAV-borne data was compared to an airborne magnetic survey flown at an approximate 75m mean terrain clearance. This case study demonstrated that UAV-borne magnetic surveys can reliably collect industry standard magnetic measurements at an increased spatial resolution over manned airborne magnetic surveys. The enhanced interpretive ability of the 3D UAV-borne magnetic data identified structural controls and fluid migration pathways potentially related to gold mineralization that were not clearly resolved with the airborne magnetic data alone.

Preferred Platform: Oral Presentation

Student Presenter: Y

Stress-induced magmatism on a flexural plate: correlating temporal-spatial relationships between the Cretaceous OMB and CCKC

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The Cordilleran Orogen of western North America is characterized by the Cretaceous Omineca Magmatic Belt (OMB), a northwest-southeast striking belt of granitoid plutons that extends from Alaska to the continental US. About 1000 km to the east of and parallel to the OMB is a 4000 km long, N-S striking, kimberlite magmatic belt called the Central Cretaceous Kimberlite Corridor (CCKC). Kimberlite magmatism in the CCKC was coeval with the termination of OMB magmatism. Cordilleran magmatism, including the OMB, is commonly explained in terms of long-lived east-dipping subduction beneath the west margin of the continent. However, explaining coeval magmatism in the OMB and CCKC by east-dipping subduction is problematic. Here we suggest that the CCKC and OMB magmatism are linked and both products of west-dipping subduction of North American lithosphere beneath the Cordillera. In this model, the OMB is a magmatic arc caused by dehydration of the subducting slab and its termination marks slab-breakoff following entry of continental North America into the trench. We propose that the CCKC is formed by extensional stress acting on the lower surface of the continent as it flexes upon entry into the trench. We set up a semi-infinite beam model as an analogue to the flexural plate, analyzing the stress distribution at the lower surface of the elastic portion of the subducting continental plate. We show that the CCKC occurs where tensile stress develops at the bottom of the flexural plate. The maximum tensile stress at the base of the lower plate relative to the first node (deflection is 0) matches the ~750 km distance between the CCKC and the inferred trench. Our model explains Cretaceous North American kimberlite magmatism as a product of a tensile stress acting on the subducting, lower (flexural) plate of a west-dipping subduction zone.

Preferred Platform: Oral Presentation

Student Presenter: Y

**A two-dimensional Voronoi cell model in Bayesian inversion of surface wave dispersion:
Application to the Cascadia forearc**

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The majority of tomographic studies that consider surface wave dispersion data implement a two-step inversion procedure. The first step involves linearized inversion of measured path-averaged dispersion data to estimate maps of group/phase velocity at specific periods of interest onto a predefined grid. The next step is to extract individual dispersion curves at each grid point and invert for a one-dimensional velocity model. Combining the inversion results at each grid point produces a pseudo-three-dimensional velocity model. In this work, we propose a methodology that bypasses the linearized inversion procedure by instead solving directly for the final velocity model. Synthetic dispersion curves are compared directly with the path-averaged dispersion between two seismic stations, as opposed to the interpolated dispersion curve at particular grid points, which are typically artificially smoothed by the linearized inversion procedure. In this way, the resulting velocity model intrinsically accounts for interstation path density and maps data errors to the model space. This initial study considers a cross-sectional velocity model parameterized using nearest-neighbor interpolation (Voronoi cells). This is a simple and parsimonious way to define general structure in two dimensions, and can be easily scaled to three dimensions. We consider the inversion of dispersion data within a trans-dimensional Bayesian framework in order to quantify the posterior probability density (PPD) of the model parameters. This method considers the number of model parameters (i.e., Voronoi cells) required to describe the velocity structure as unknown in the problem, and allows model complexity to be inherently determined by data information content, not by subjective regularization. The methodology developed here is applied to data from the dense linear CASC93 seismic array in the forearc of central Cascadia.

Preferred Platform: Poster Presentation

Student Presenter: Y

Chemical geodynamics revisited: carbon pathways in Earth's deep interior through deep time

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Carbon is one of the most important elements in the Earth, but the mass distribution and temporal evolution of carbon in Earth's deep interior are relatively poorly understood. Using an approach called chemical geodynamics that combines simple reservoir models with computational models of mantle dynamics, we compute time-dependent models for the evolution of carbon in the major reservoirs through Earth's history. At the present time, the largest reservoirs for carbon are the core, the mantle, and the continental crust. The mantle may be further divided into multiple reservoirs. Early in Earth's history the atmosphere was also a major reservoir for carbon. The smaller reservoirs - the oceans, the present atmosphere, and organic carbon - contain far less than the major reservoirs. It has been proposed that the early atmosphere was also a major reservoir of Earth's carbon, by analogy to Venus, which has a carbon-rich atmosphere. Atmospheric CO₂ reacts with eroded calcium silicates to produce calcium carbonates plus silica; this reaction extracted essentially all carbon from the atmosphere to the continental crust. The flux of carbon that has been introduced into the mantle and remixed into the upper mantle reservoir is not well constrained. Substantial amounts of carbon could have been extracted from the mantle, if the emissions due to volcanism exceeds the return to the mantle through subduction.

Preferred Platform: Poster Presentation

Student Presenter: N

CIG_01: Mantle Convection: Computational Infrastructure for Geodynamics

Conveners: Julian Lowman¹, Miki Nakajima², Allen McNamara³ and Louise Kellogg⁴

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Geodynamic mechanisms for the preservation of large-scale primordial heterogeneity in the Earth's mantle

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Seismic imaging of subducted Farallon and Tethys lithosphere in the lower mantle has been taken as evidence for whole-mantle convection, and efficient mantle mixing. However, geochemical signatures of Phanerozoic magmatic rocks provide evidence for the long-term persistence of primordial reservoirs somewhere in the mantle. In this presentation, I present several geodynamic mechanisms for sustaining large-scale (primordial) heterogeneity in the Earth's mantle. Mantle flow is controlled by rock density and viscosity. Variations in intrinsic rock density, such as due to heterogeneity in basalt or iron content, can induce layering or partial layering in the mantle. Such layering can be sustained in the presence of persistent whole mantle convection due to active “unmixing” of small-scale heterogeneity in low-viscosity domains, e.g. in the transition zone or near the core-mantle boundary. Alternatively, a primordial Fe-enriched layer can avoid any significant mixing over billions of years due to a large intrinsic density anomaly, consistent with the seismic imaging of thermochemical piles in the deep mantle. On the other hand, lateral variations in intrinsic rock viscosity, such as due to heterogeneity in Mg/Si, strongly affect the mixing timescales of the mantle. In the extreme case, intrinsically strong rocks may remain unmixed through the age of the Earth, and persist as large-scale domains in the mid-mantle (or “bridgmanite-enriched ancient mantle structures”: BEAMS) due to focusing of deformation along weak conveyor belts. That large-scale lateral heterogeneity and/or layering can persist in the presence of whole-mantle convection can explain the stagnation of some slabs, as well as the deflection of some plumes, in the mid-mantle. Thus, several large-scale reservoirs for the long-term storage of enriched and/or depleted primordial heterogeneity may have survived despite long-term vigorous whole-mantle convection.

Preferred Platform: Oral Presentation

Student Presenter: N

Constraints on early Earth tectonics via convection models with grainsize evolution

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The operation of plate tectonics on Earth requires rheological weakening in the lithosphere that forms weak plate boundaries, driven by mantle convective forces. While plate tectonics of course operates on the modern Earth, whether it has operated throughout Earth's history, or was untenable early in the Earth's life, is not well known. A hotter mantle and different heat production rates can change the forces available in the lithosphere for forming plate boundaries. Some models employing a pseudoplastic rheology for the lithosphere have suggested that a hotter mantle is a problem for plate tectonics, as lithosphere stresses decrease with increasing mantle temperature. However, other processes, such as grainsize evolution, could be crucial for forming weak plate boundaries as well. Here I show how using grainsize evolution as a mechanism for forming plate boundaries leads to different predictions about early Earth tectonics, as a result of fundamental differences in the physics behind the plate generation mechanisms. In particular I find that a hotter, internally heating dominated Earth is not a significant impediment to plate boundary formation, subduction, and surface plate mobility, because the viscous dissipation, which drives grainsize reduction, increases with increasing mantle temperature. A hotter Earth does lead to more episodic subduction, over a range of timescales, and a more sluggish subduction relative to flow in the mantle interior, which can be quantified using timeseries analysis and scaling. These changes in subduction style with mantle temperature are potentially important for explaining geological observations of early Earth crust formation processes.

Preferred Platform: Oral Presentation

Student Presenter: No

**The influence of curvature on convection in a temperature-dependent viscosity fluid:
implications for the 2D and 3D modeling of moons**

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Convection in terrestrial bodies occurs within spherical shells described by the ratio, f , of their bounding radii. Previous studies that have modeled convection with a temperature-dependent viscosity noted the strong effect of f on transition to the stagnant-lid regime. Here, we analyze stagnant-lid convection (SLC) in 2D and 3D systems with curvatures including relatively small-core shells (f as small as 0.2) as well as in thin shell and plane-layer cases. Several peculiarities of convection in a strongly temperature-dependent viscosity fluid are identified for both high and low curvature systems. We demonstrate that effective Rayleigh numbers may differ by orders of magnitude in systems with different curvatures, when all other parameters are maintained at fixed values. Furthermore, as f is decreased, the nature of SLC in small core bodies shows a divergence in the temperature and velocity fields found for 2D annulus and 3D spherical shell systems. In addition, substantial differences in the behavior of thin shell ($f=0.9$) and plane-layer (Cartesian geometry) models occur in both 2D and 3D, indicating that the latter (emulating a toroidal topology rather than spherical) may be inappropriate approximations for modeling variable viscosity convection in thin spherical shells. Our findings are especially relevant to understanding and accurately modeling the thermal structure that may exist in bodies characterized by thin shells (e.g., $f=0.9$) or relatively small cores, such as shells comprising the Galilean satellites and other moons.

Preferred Platform: Oral Presentation

Student Presenter: Y

Composition dependent properties and their effects in the early Earth

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Numerical models of mantle convection help our understanding of the complex feedback between the plates and deep interior dynamics through space and time. These models for present day mantle dynamics are often constrained by present day observations, but numerical models for the much hotter early Earth are less well constrained and consequently the dynamics are less well understood. One theory for the early Earth is that a large hot magma ocean was trapped near the core-mantle-boundary after formation during differentiation. This basal magma ocean would likely contain different elements from the surrounding mantle; it could even be iron-rich from the core. In this study we implement numerical models for such a scenario and examine their effects on the surface stresses. Our models start with an initial state of stagnant-lid convection and a basal magma ocean layer in a hot, vigorously convecting mantle. We impose varying compositions, viscosities and conductivities to the basal magma ocean layer, and we look for threshold parameters that yield the kinds of mobile surfaces we see in present day plate tectonics.

Preferred Platform: Oral Presentation

Student Presenter: N

Combining Large-scale Numerical Simulations with Observational Data Sets to Constrain the Thermochemical History and Interior Dynamics of Mars

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Our knowledge of the geophysical, geochemical and geological processes that shape the evolution of terrestrial planets in our Solar System and beyond is continuously improving with the increasing amount of data returned from space missions and telescopes. However, in the absence of direct measurements, the interior dynamics of terrestrial bodies is poorly known and our understanding of the interior evolution of terrestrial planets stems from laboratory experiments and large-scale numerical simulations. The latter have grown to become one of the most powerful methods to investigate the temporal evolution of mantle flow in a 3D spherical geometry with variable viscosity and including chemical heterogeneities. Today, large-scale numerical simulations of thermal evolution can be used together with a number of observational constraints from geodetic, geochemical and geological investigations of Mars to reconstruct its thermochemical history. Models show that the early evolution is characterized by the cooling and crystallization of a global magma ocean, which plays an important role for the subsequent interior dynamics and magmatic history. Mars has been volcanically active up to the recent past. The concentration of volcanic activity in Tharsis and Elysium provinces indicates the location of mantle plumes beneath such regions over geological timescales. 3D thermal evolution models suggest that prominent mantle plumes modulate the temperature distribution in the deep interior, while the crustal thickness pattern and the crust radioactivity affect the temperature variations in the shallowest layers. Future in-situ seismic and heat flow measurements of the InSight mission will provide the most direct data of the interior of Mars. Such data combined with 3D thermal evolution models will help to characterize the present-day thermal state and interior structure of Mars and to improve our understanding of how the interiors of terrestrial planets evolve with time.

Preferred Platform: Oral Presentation

Student Presenter: N

Investigating different patterns of slab deformation in the lower mantle

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The geometry of slabs within the upper mantle have been relatively well-imaged by tomography and regional seismic studies; however, the style of slab deformation in the lower mantle remains poorly understood. Although tomography models reveal that the lower mantle beneath paleo-subduction regions are faster-than-average, the resolution is not high enough to resolve how slabs are actually deforming there. Slabs have long been hypothesized as viscous, tabular sheets that subduct at the surface, descend through the mantle, and impinge on the core-mantle boundary (CMB). Geodynamical studies have shown a wide range of possible deformational behaviors, ranging from stiff, buckling slabs to more-ductile masses of accumulating slab material undergoing pure shear. Of particular interest is how rheology and 3D spherical geometry control the shape and deformational style of slabs as they descend deeper into the mantle. We performed high resolution 3D spherical calculations to explore slab deformation in deep mantle as a function of slab strength. In our model, kinematic velocity boundary conditions are imposed on the surface to simulate a moving plate which guides the formation of a subducting slab. In addition, a viscosity jump at the transition zone is applied. We find that although a slab subducts as a large tabular sheet from the surface, it doesn't always maintain such geometry. Instead, it typically breaks apart into a few smaller and narrower sheets which can even turn into cylindrical-shaped downwelling after subducting into deep mantle. Since seismic anisotropy is hypothesized to originate from crystal preferred orientation (CPO) in a slab when it impinges on the CMB and is predicted with significant help of time-dependent deformation information from the geodynamic models, our findings on lower mantle slab deformation patterns may enhance the understanding towards the cause of characteristic patterns of predicted seismic anisotropy.

Preferred Platform: Oral Presentation

Student Presenter: Y

Incident angle of subducting slabs against the 410- and 660-km discontinuities

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The long-term evolution of subduction systems is governed in part by the buoyancy forces in the downgoing plate associated the transition zone phase changes. Whether the plate penetrates into the lower mantle, stagnates at the base of the transition zone, or experiences a change in mode over time affects the overall pull that a downgoing plate can exert, which has implications for the behavior of plates at the surface. In particular, due to the negative Clapeyron slope associated with the 660-km discontinuity, the initial incident angle of a downgoing plate against the 660-km discontinuity will affect whether that plate will initially penetrate or stagnate at the base of the transition zone. Specifically, a steeper initial angle will promote initial penetration, while a shallower angle will promote stagnation. Using a 2D thermomechanical finite difference code, we explore the effect of varied initial incident angles, over a range of Clapeyron slopes and contrasts in density and viscosity across the 660-km discontinuity. We also consider the effect of the 410-km phase change, whose positive Clapeyron slope may help steepen the downgoing plate's descent.

Preferred Platform: Poster Presentation

Student Presenter: Y

Three-dimensional thermal convection in a spherical shell with a free surface

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Simple symmetric modes of convection of the Earth's mantle can be used to validate numerical codes and predict global dynamics patterns. We use an incompressible and isoviscous Rayleigh-Bénard thermal convection benchmark at infinite Prandtl number in a spherical shell to compare the state-of-the-art finite element code ASPECT with the previously benchmarked numerical code CitcomS. Thermal convection in the spherical shell is initiated by various perturbations of the conductive geotherm given by the sum of 2 spherical harmonics of different amplitude. We explore the sensitivity of the initial and steady-state root mean square velocity, average temperature and Nusselt number measured at both inner and outer boundaries to resolution for a range of Rayleigh numbers. Although the original benchmark is formulated with free slip boundary conditions, we explore for the first time the effect of a free surface on such calculations and compare the measured topography to dynamic topography measurements. We find that using a free surface top boundary, the convection pattern is altered and more sensitive to model resolution. For free-slip and free surface, we will report the geoid values as measured using the current ASPECT plugin which is based on spherical harmonic expansion.

Preferred Platform: Poster Presentation

Student Presenter: N

CIG_01

The influence of compositional heterogeneity in mantle convection models on a plate-like surface velocity field

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Numerous studies have investigated the conditions required to generate plate-like surface characteristics in mantle convection models. The introduction of a stress-dependent rheological component allows for the onset of surface mobility and the generation of localized regions of deformation. Seismological evidence suggests that modelling Earth-like mantle convection may require the introduction of rheological complexities that exist in the lower mantle. The two Large Low Shear-wave Velocity Provinces (LLSVPs) overlying the core mantle boundary (CMB) appear in all shear wave tomography models. Multiple studies have suggested that the LLSVPs are thermochemical and exist stably on the order of at least 100 million years. Previous geodynamic studies in Cartesian geometry have indicated an impact of compositionally anomalous and intrinsically dense (CAID) material on surface features, such as the number and size of plates. Implementing global dynamic models in a spherical annulus geometry,

Preferred Platform: Poster Presentation

Student Presenter: Y

The effect of dynamic tracer repositioning on conservation properties in thermochemical convection models

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The Earth's mantle is convecting vigorously and is characterized by a thermal Rayleigh number that is several orders of magnitude greater than the critical value. Accordingly, the modelling of terrestrial mantle convection is an inherently computationally demanding problem. Moreover, intrinsic density anomalies due to compositional variation in the mantle must be accounted for to model both lithospheric chemical heterogeneity and possible compositional anomalies in the deep mantle. Consequently, particularly due to the low diffusivity at the boundaries between chemically distinct materials, the modelling of thermochemical convection entails its own distinct challenges. Here a new model is introduced, that calculates both the evolving thermal and compositional fields by using Lagrangian tracers that advect through an Eulerian grid. We first demonstrate the accuracy of the Lagrangian methodology in calculating thermal convection and then analyze the effect of a tracer repositioning algorithm on reducing the cumulative mass error in thermochemical convection calculations featuring a range of tracer densities. We conclude by examining the influence of thermal and compositional Rayleigh number on the stability of compositionally anomalous and intrinsically dense material in the deep mantle, specifically identifying Rayleigh number ratios that result in complete mixing, pile formation and stable layer regimes.

Preferred Platform: Poster Presentation

Student Presenter: N

A scaling relationship for impact-induced melt volume

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During the late stages of planetary accretion, protoplanets experience a number of giant impacts and extensive mantle melting. The impactor's core sinks through the molten part of the target mantle (magma ocean) and experiences metal-silicate partitioning. To understand the chemical evolution of the planetary mantle and core, determining the impact-induced melt volume is important because the partitioning strongly depends on the ranges of the pressures and temperatures within the magma ocean. Furthermore, the melt volume would also affect the structure, heterogeneity, and long-term evolution of the planetary mantle. Previous studies have investigated the effects of small impacts (i.e. impact cratering) on melt volume, but those for giant impacts are not well understood yet. Here, we perform giant impact simulations to derive a scaling law for melt volume as a function of impact velocity, impact angle, and impactor-to-target mass ratio. We use smoothed particle hydrodynamics method (a particle method) and the code iSALE (a grid-based method) to compare their outcomes. Our simulations show that these two codes generally agree as long as the same equation of state is used. Our scaling law also provides the depth and width of the magma ocean, which would help us modeling the chemical evolution of the planetary core and mantle. We also discuss how our model would affect geodynamical modeling of planetary interiors.

Preferred Platform: Poster Presentation

Student Presenter: N

Power Spectrum Measurements of Mantle Convection in a 2D Annulus Domain

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We present results of dimensionless convection experiments in 2D spherical domains obtained with both ASPECT and ELEFANT geodynamical codes. The domain is scaled such that the mantle thickness and the prescribed temperature difference between the inner and outer boundaries are one. Free-slip boundary conditions are used and the flow is modelled under the Boussinesq approximation. The initial temperature profile is linear with a superimposed spherical harmonic perturbation of small amplitude. We have run series of experiments in which the Rayleigh number, the order N_0 of the initial spherical harmonic perturbation, and the rheology type (linear viscous, temperature-dependent, temperature- and strainrate-dependent) were varied. At startup the temperature perturbation gives rise to N_0 convection cells. For values of $N_0 > 4$ these undergo a series of spatial reorganizations with decreasing cell numbers, ultimately reaching a statistical steady state corresponding to a final constant cell number $N < N_0$. In this work, we specifically look at the time evolution of the root mean square velocity values, the volume averaged temperature values, the inner and outer heat flux, and their power-spectra. We systematically analyze the complete sets of experiments and show how various numerical parameters such as mesh resolution affect the results for both codes.

Preferred Platform: Poster Presentation

Student Presenter: no

CIG_03: Lithosphere Dynamics: Computational Infrastructure for Geodynamics

Conveners: Margarete Jadamec¹, Laurent Montesi², Claire Currie³, Louise Kellogg⁴

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Topographic controls on magmatism during rifting

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Extension at intra-continental rifts is commonly accompanied by decompression melting associated with mantle upwelling. Recent observations have suggested that the locus of dike intrusion and subsequent volcanism may be closely related to bounding fault activity and the growth of rift topography. Because magmatic fissures tend to propagate along the direction of most-compressive stress, dike injection is sensitive to changes in the stress field imparted by topographic loads and/or tectonic or flexural stresses. In particular, the accumulation of rift flank relief induces compression at the base of the lithosphere, which inhibits the intrusion of blade-like dikes at depth, and favors the opening of shallow fissures that deliver magma to the surface. Conversely, dike injection exerts a strong control on topography development, as magmatic intrusions typically accommodate a large fraction of the plate separation at a rift, and can in some instances deactivate border faults that take up the remainder of the extensional strain. This opens the possibility of complex feedbacks between the build-up of topographic relief and the dynamics of rifting. Here we use numerical models to quantify the effect of ambient stresses on the geometry of dike emplacement and the retroactive effects of dike emplacement on ambient stresses (and on adjacent faults) in a self-consistent manner. In particular, we consider the role of surface processes in modulating the intensity of the topographic feedbacks on magma emplacement by alleviating topographic loads and promoting a topographic steady-state as opposed to continuously growing topography.

Preferred Platform: Oral Presentation

Student Presenter: No

Lithosphere dynamics in the central Andes: Implications for magmatism and surface topography

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The central Andes of South America is the second largest orogen on Earth, where subduction has resulted in significant crustal shortening and thickening. Geophysical observations show that the mantle lithosphere below much of the orogen is anomalously thin. At the surface, the high-elevation hinterland is characterized by widespread magmatism and transient ~100-km wide basins. These appear to be spatially and temporally correlated: the basins are systematically found seaward of major calderas, with basin formation predating the eruptions. Furthermore, volcanism overlies areas of thin mantle lithosphere and appears to have migrated from the backarc toward the trench. We propose that the basins and magmatism are the direct results of gravitational lithosphere thinning and subduction-induced mantle flow. Using thermal-mechanical numerical models, we show that the formation of localized high-density eclogitized lower crust depresses the overlying surface, creating a basin. The foundering crust entrains the adjacent mantle lithosphere, and both are sheared and carried toward the trench by subduction-induced mantle wedge flow. This creates asymmetric lithosphere removal, and the formation of a thinned region of mantle lithosphere on the landward side of the basin. As mantle upwells into this gap, mafic and felsic melts are created through mantle decompression and rapid crustal heating. This process is modulated by the crustal strength, such that a weaker crust enhances lithosphere removal and melting but reduces the depth and duration of the basin. Overall, the models demonstrate the importance of interactions between localized lithosphere instabilities and regional mantle flow for the topographic and magmatic evolution of an orogen.

Preferred Platform: Oral Presentation

Student Presenter: N

Insights on fore-arc sliver processes from 3D geodynamic models of flat slab subduction in Alaska

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Fore-arc slivers occur in ~50% of modern subduction zones (Jarrard, 1986). They are commonly associated with oblique convergence and are bounded between a trench and a large intracontinental shear zone, which allows them to move independently from the rest of the upper plate. However, the dynamics governing the interactions between the resisting forces from within the intracontinental shear zone and the driving forces of the subducting plate are not well understood. Here, we use high-resolution, 3D numerical models of oblique flat slab subduction in south-central Alaska to examine this dynamic interaction. The geodynamic models show that the flat slab drives northwest motion of the Wrangell block fore-arc sliver, where models with a weak (10^{17} Pa s) intracontinental shear zone, the Denali fault, and strong interplate coupling (10^{21} Pa s) produce the fastest motion of the fore-arc sliver (~10 mm/yr). When compared to GPS observations, the models with a composite (non-Newtonian) rheology provide the best fit to the observed direction of Wrangell block motion. The models also predict along strike variability in Denali fault motion and suggest that the Alaska flat slab drives at least 20% of the observed Quaternary slip rates across the Denali fault. These models imply that a sufficiently weak intracontinental shear zone is required for fore-arc slivers to move at comparable rates to observation.

Preferred Platform: Oral Presentation

Student Presenter: Y

Western Pacific subduction dynamics: Slab dips, plate velocities, and mantle pressure

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While it is well established that the “slab pull” of negatively buoyant oceanic plates is the primary driving force of plate tectonics, the dynamic details of subduction have proved difficult to pin down. We use the Philippine Sea Plate region of the western Pacific as a site to explore links between the kinematic observables (e.g. topography and plate motions) and dynamics of subduction systems (e.g. mantle flow, mantle pressure). To first order, the Philippine Sea Plate can be considered to be the central plate of a double slab system containing two slabs that dip in the same westward direction. This configuration presents the opportunity to explore subduction dynamics in a setting where two proximal slabs may interact via subduction-induced mantle flow and/or lithospheric stress transmission, with the strength of such interactions having strong implications for the geodynamic properties of subduction zones. We use numerical models to develop relationships between regional subduction dynamics and kinematic properties which, when combined with observations, allow us to isolate the processes operating in the Philippine Plate region. Our results suggest that positive pressure build-up occurs in the asthenosphere between the two slabs (Izu-Bonin-Mariana and Ryukyu), and that this is responsible for producing much of the kinematic variability observed in the region. We then extend our analysis to larger spatial scales using a semi-analytical modeling technique. While regional models, with small plates, are sufficient to explain the spatial variability in subduction kinematics (e.g. along-strike variations), consideration of the large-scale subduction geometry is required to reconcile absolute values of subduction parameters (e.g., average slab dip, as opposed to spatial trends). We therefore argue that global plate geometries exert a pronounced control on local subduction parameters.

Preferred Platform: Oral Presentation

Student Presenter: N

Global Lithosphere Models Coupled to 3-D mantle Convection: Examples from North America and Central Asia

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We investigate global models of lithosphere deformation and score model output with surface motions, strain rates, earthquake moment tensors, and stress orientations from the World Stress Map. Models possess the effects of topography and lithosphere structure (Gravitational Potential Energy differences) and are coupled to mantle flow models. Mantle flow models are derived from global tomography models, using a radial viscosity structure. Models with lateral viscosity variations (lithosphere keels) have also been investigated. We have tested over 50 global tomography models and evaluated characteristics of mantle flow that yield the lowest misfit with surface observations. We show examples from North America and Central and East Asia. Gradients of GPE play the most significant role in affecting gradients in deviatoric stress and strain within the lithosphere of continental deformation zones. Models are not sensitive to smaller-scale convection beneath these regions (radial and tangential tractions). On the other hand, we show that large-scale patterns of mantle flow are key in matching observations within the lithosphere, including plate motions and large-scale patterns of stress; tractions originating from the long-wavelength patterns of mantle flow integrate over thousands of kilometers to be important. The high sensitivity to lithosphere structure suggests that the greatest opportunities for making progress in understanding lithosphere dynamics hinges on improved estimates of lithosphere structure, including reliable density estimates for the crust and uppermost mantle, along with an improved understanding of lithosphere rheology.

Preferred Platform: Oral Presentation

Student Presenter: N

Width of imbricated thrust blocks and the strength of accretionary wedges

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Imbricated thrust faults are prominent structures that characterize accretionary wedges around the world. Studies of the mechanics of these systems have a rich history from laboratory analog modeling, and more recently from computational simulations, however, our knowledge of what controls the spacing of the major thrust faults remains immature at best. We tackle this problem using a finite difference, particle-in-cell numerical method that simulates visco-elastic-plastic deformation with a Mohr-Coulomb brittle failure criterion. The model simulates a horizontal base that moves toward a rigid vertical backstop, carrying with it an overlying layer of sediment with a specified basal friction. The sediment layer has a greater frictional strength than the base, is cohesive, and is initially uniform in thickness. As the sediment layer contracts, it forms a wedge composed of sequential thrust faults with a mean taper angle consistent with that predicted by an ideal non-cohesive, critical Coulomb wedge. The width of individual thrust blocks are maximum when they first form at the toe of the wedge, and then decrease with time in proportion to mean shortening rate across the whole wedge. The initial width of the frontal thrust block therefore defines the scale for the widths of all thrust blocks. Model results show that the width of the frontal thrust block increases linearly with the thickness of the incoming sediment layer and increases linearly with the coefficient of friction of the sediments. Block width shows only a weak inverse relation with the friction along the basal decollement. These results open the possibility of developing a method for using observations of thrust block widths to estimate the strength of wedges and their base as a compliment to classical critical Coulomb wedge theory.

Preferred Platform: Oral Presentation

Student Presenter: No

Numerical modeling of flat-slab subduction: Influence of lithosphere structure and rheology on slab depth

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A sub-horizontal oceanic plate (flat-slab) geometry is observed in ~10 percent of modern subduction zones. In both western North and South America, several flat-slab segments occur at present-day or are inferred for the past. The flat-slabs occur at a variety of depths, from just below the Moho to ~200 km depth. However, the mechanisms that cause slab flattening and the factors that control the flat-slab depth remain uncertain. In this work, we use 2D thermal-mechanical models using the SOPALE code to study subduction dynamics for both old (e.g. Farallon Plate) and young (e.g. Nazca Plate) subducting plates, with ages of 100 Ma and 30 Ma, respectively. Old oceanic plate models include a 600 km wide oceanic plateau, and we ran a series of experiments to test the influence of different continental thicknesses (60 km-240 km) and continental mantle lithosphere strengths (approximating conditions from wet olivine to dry olivine) on slab flattening. We use the same model set up for young oceanic plate, except that we also consider models with no oceanic plateau. Consistent with earlier studies, we find that creation of a flat slab requires both trenchward continental motion and a buoyant oceanic plateau (i.e., non-eclogitized crust) for an old oceanic plate; for a young plate, a plateau is not necessarily needed as the plate is hotter and therefore more buoyant. Our models demonstrate that the upper plate plays an important role in slab dynamics. The depth of the flat slab is mainly controlled by two factors: (1) the continental thickness and (2) the strength of the continental mantle lithosphere. A shallow flat slab requires either a thin continent or, if the continent is thick, its mantle lithosphere must be relatively weak so that it can be displaced by the flattening slab. Moreover, the results show that flat slab is able to remove the lower 0-90 km of continental mantle lithosphere, with greater removal for a weaker lithosphere.

Preferred Platform: Oral Presentation

Student Presenter: Y

The Effects of Ridge Axis Width on Mantle Melting at Mid-Ocean Ridges.

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Plate divergence at mid-ocean ridges induces mantle upwelling and melting. Whereas mid-ocean ridge models typically assume that divergence takes place only in a narrow zone that defines the ridge axis, more complex patterns of divergence are occasionally observed: the rift axis can be 20 km wide at ultraslow spreading center; overlapping spreading centers contain two parallel axes; rifting in backarc basins may feature a series of parallel spreading centers. Distributing plate divergence over several rifts reduces the intensity of upwelling and limits melting. Can this have a significant effect on the crustal thickness and on the mode of melt delivery at the seafloor? We address this question by modeling mantle flow and melting underneath two spreading centers separated by a rigid block. We adopt a non-linear rheology that includes dislocation creep, diffusion creep and yielding and include hydrothermal cooling by enhancing thermal conductivity where yielding takes place. The crustal thickness decreases if the rifts are separated by 30 km or more but only if the half spreading rate is between 1 and 2 cm/yr. A single upwelling remains the norm until the rifts are separated by more than 15 km in the fastest ridges or 50 km at ultraslow spreading centers. Hydrothermal cooling stabilizes the central upwelling by preventing hot mantle from reaching the surface at individual spreading center. In extreme cases, distinct, highly asymmetric upwellings develop under each spreading center. In that case, melt delivery might drive further and further the divergence centers, whereas, when a single upwelling is retained, melt delivery would drive the spreading centers closer together. Thus, the system composed of two rifts is unstable and, if observed in nature, indicates either a transient geodynamic regime, like a recent change in spreading rates, or control structural or stress heterogeneities.

Preferred Platform: Oral Presentation

Student Presenter: N

Grain by Grain to Plate Tectonics

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We explore the microphysics of weakening of lithospheric materials, and in particular the role of mineral grain size on lithospheric strength. The mechanical weakening due to grain size reduction, or damage, has been proposed as a mechanism for strain localization, resulting in the formation of deep lithospheric shear zones, or even new tectonic plate boundaries. For example, we demonstrate that rapid grain size reduction in the ductile portion of the lithosphere can enable, or at least significantly facilitate, the collapse of a passive margin and initiate a new subduction zone. The grain size of a material changes as a result of diffusion-driven grain growth, or, for deforming materials, in a process of dynamic recrystallization (DRX). The microphysics of DRX largely revolves around the dynamics of intragranular defects, namely dislocations. In a single-phase material, the driving forces for DRX arise from the heterogeneity in dislocation density, as well as the grain boundary curvature and surface tension. The driving forces for DRX can interact, and in our newly developed model we explore their competing effects. Our preliminary results show that as grains grow, to minimize their surface energy, they eventually cross into the dislocation creep regime and accumulate dislocations. Increasing the grain's dislocation density, and the associated internal energy, impedes the grain growth driven by variation in grain boundary curvature, thus retarding the healing of previously damaged zones. Upscaling these microphysical processes to the continuum scales relevant for geodynamic models is important for understanding the retention and reactivation of weak zones in the cold ductile lithosphere, which is imperative for generation of plate tectonics on Earth.

Preferred Platform: Oral Presentation

Student Presenter: Mulyukova

Convective instability in horizontal decompaction channels in planetary lithospheres

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As melt travels upwards from the convecting mantle and through the lithosphere of planetary bodies, it likely becomes trapped below a horizontal layer (permeability barrier) at depths too deep to be readily tapped by dikes and fractures. We investigate convection in the melt rich, highly porous layer below the permeability barrier, known as the decompaction channel as a potential mechanism for collecting melt and breaching the barrier. Using the finite element code ASPECT with melt migration extension, we model the formation and evolution of permeability barriers and decompaction channels in two dimensions, representative of a single plate planetary lithosphere. Our model consists of a 2D box, 150 km in height and 80 km in width, representative of a younger, warmer Mars-like lithosphere. In our models, melt ascends, forming a permeability barrier near 100 km depth and a 10-20 km thick decompaction channel forms underneath. After a 1-3 million year time period, dependent on density differences between solid and liquid, cold downwellings consisting of both solid and trapped melt descend from the top of the decompaction channel due to the crystallization of melt. Upwellings bring hot melt and accompanying solid back to highly porous pockets near the top of the decompaction channel. New drips form near the top of the channel as the newly arrived melt crystallizes. The convection process is not purely thermally driven, as it occurs even when the thermal Rayleigh number is less than the critical Rayleigh number. The density difference between the fully crystallized aggregate at the top of the channel and the melt rich aggregate appears to be a more significant driver for convection. Melt is focused to highly permeable pockets at the top of the decompaction channel, where crystallization and latent heat release occur. These melt pockets may initialize the mechanism that allows melt to rise past the level of the permeability barrier.

Preferred Platform: Oral Presentation

Student Presenter: Y

Response of a continental rift zone to a passing weak plume: insights from the Rio Grande rift

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Geodynamic models of plume-lithosphere interaction have been successful in demonstrating that continental rifting may result from a rising mantle plume. In those models, the rising mantle plume thins and weakens the lithosphere, while dynamic uplift results in extensional deformation. The Rio Grande rift in the southwestern U.S. provides a natural example to study what happens during continental rifting when a focused mantle upwelling zone is present below the rift. Mantle flow patterns derived from tomographic images indicate that a “weak plume” passed underneath this rift in the late Miocene-Early Pliocene. We argue that this weak plume resulted in uplift, which caused the formation of a late Miocene–early Pliocene unconformity that developed mainly along the flanks of most rift basins. The age of its associated lacuna is spatially variable but falls within 8–3 Ma (mostly 7–5 Ma) and thus is synchronous with eastward tilting of the western Great Plains (ca. 6–4 Ma). We calculated geoid-topography ratios, which suggest that the elevation of the northern part of the Rio Grande rift is still dynamically compensated. We find no evidence of accelerated or focusing of rift opening as predicted by geodynamic models; instead, there are indications that rift opening slowed down during passage of the weak plume.

Preferred Platform: Oral Presentation

Student Presenter: N

Evolution of Long-Term Tectonics across the Indo-Burman Range

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The potentially active tectonics of the subduction zone across the Indo-Burman Range (IBR), which formed due to the collision between the Indian Plate and Burma microplate, remains controversial. Since the faulting mechanism within this region is not well understood, this research project aims to study evidence of active tectonics by investigating the geomorphology, active crustal deformation and seismicity of the range, and applying these observations and measurements to constrain a three-dimensional deformation model. Geomorphic indices, geodetic measurements and seismicity catalogs will be used to constrain models of the long-term tectonics and dynamics of lithospheric and mantle deformation across the IBR. Numerical modeling software, i.e. ASPECT and LaMEM, will provide a broader conceptualization of the complex plate-boundary deformation at depth. By integrating observational approaches from different fields, i.e. geomorphology, geodesy and seismology, the dynamic models will help to better understand the underlying tectonic processes and resolve whether the subduction thrust itself continues to be active. The improved understanding of the tectonics in this region is important, because the different types and magnitudes of earthquakes in alternative scenarios greatly impact the inferred geohazards.

Preferred Platform: Poster Presentation

Student Presenter: Y

In situ rheology of the oceanic lithosphere along the Hawaiian Ridge

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An accurate knowledge of lithosphere rheology is important to many solid-earth geophysical problems including those associated with earthquakes, subduction dynamics, and plate tectonics. Our current understanding of lithosphere rheology, however, is primarily derived from laboratory deformation experiments, which rely on large extrapolations of strain rates to natural conditions. An alternative approach is to exploit information provided by natural phenomena. Zhong & Watts [2013] modeled in situ flexure around the main Hawaiian Islands, and found a lithosphere rheology that was much weaker than predicted by laboratory experiments. We perform an in situ study along the older Hawaiian Ridge, which contains a diversity of volcano sizes loaded on seafloor of nearly constant age (85 ± 8 Ma). This situation allows analysis of the lithospheric flexural response to a wide variety of loads with nearly constant age-dependent thermal structure. Our dataset includes marine gravity and multi-beam bathymetry data collected onboard the Schmidt Ocean Institute's R/V Falkor. The data are combined with forward models of lithosphere flexure to obtain posterior probability density functions for model parameters that control the lithosphere's flexural response to a given load. The parameters are frictional coefficient μ , which controls the brittle strength of the shallow lithosphere; the pre-exponential term F controlling the strength of low-temperature plasticity; crustal density ρ ; and thermal age of the lithosphere t . We confirm the findings of Zhong & Watts [2013] for an enigmatically weak rheology using the half-space cooling model for the lithospheric thermal structure. With the plate cooling model, the rheology of Kranjc et al. [2015] is consistent with a thermal age equivalent to the true seafloor age. In contrast, the rheology of Mei et al. [2010] is probable only for appreciably younger thermal ages, requiring the hotspot to have thermally rejuvenated the lithosphere.

Preferred Platform: Poster Presentation

Student Presenter: Y

CIG_03

Continent-scale lithospheric models constrained by multiple seismic observables made by large scale seismic arrays

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With more than 2-decade of progress of large seismic arrays deployed across the world (e.g., Earthscope/USArray transportable array (TA) and POLARIS network in North America, China Array and F-net in Asia; POLENET in Antarctica), many innovations in seismic imaging have been developed (e.g., the ambient noise tomography, eikonal/Helmholtz imaging methods, and the systematic observation of Rayleigh wave horizontal-to-vertical amplitude (H/V) ratios across large seismic arrays). These new observables, together with the recently developed imaging methods (i.e., Monte Carlo joint inversion), provide the opportunity to reveal completely new views of the lithosphere across regions like the conterminous United States and Alaska, E. Asia, and west and central Antarctica. In this presentation, we will summarize the seismologic tools we have developed, display the high-resolution images of the 3-D seismic model at continental scale. Particularly, using these new seismic observables and models, we show 1) how the large scale tectonics is related to the seismic structure of the lithosphere; 2) how the large-scale mountain building process (i.e., the southern Transantarctic Mountains) is perhaps related to an ongoing lithosphere foundering process; and 3) how to move beyond seismic modeling towards the thermodynamic modeling of the lithosphere.

Preferred Platform: Poster Presentation

Student Presenter: N

Modelling of overriding plate deformation and slab rollback in the Mediterranean

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In subduction zones, the overriding plate often experiences back-arc extension caused by slab rollback and/or overriding plate retreat. These extensional basins sometimes comprise newly formed oceanic crust originated from seafloor spreading, while in other regions only stretching of continental lithosphere occurs. In the Western Mediterranean, subduction rollback resulted in a two-phase opening of the Liguro-Provençal Basin (30-16 Ma) and the Tyrrhenian Basin (8 Ma-present), with a transient quiet period in between. The cause of the non-continuous opening of these basins is not well understood, as well as the cause for the subduction to jump from the western to the eastern side of Corsica and Sardinia at the onset of extension in the Tyrrhenian Basin, leaving the Corsica/Sardinia block behind. In contrast, in the Aegean basin, where the absolute plate motion boundary conditions differ, no formation of oceanic crust in the overriding plate took place during formation of the extensional basin. To study the controlling factors on opening of the Liguro-Provençal Basin and the Tyrrhenian Basin as well as of the Aegean basin, we perform 2D numerical modelling of a central transect through the two backarc regions with the ASPECT code. We focus our study on the effect of lithospheric strength, absolute plate motions and pre-existing weakzones on the evolution of overriding plate deformation are studied. We compare the results of the numerical models to the existing geological framework. Through this study, we attempt to explain the different evolution of the Liguro-Provençal/Tyrrhenian basin and Aegean basin, which is still not well understood. The relative influence of the various controlling factors may have first order implications on overriding plate deformation in extensional basins in subduction systems in general.

Preferred Platform: Poster Presentation

Student Presenter: n

A new solver for large-scale, 3D models of coupled magma/mantle dynamics

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Many Earth system processes are controlled by the porous flow of melt through a viscously deforming solid rock matrix. The motion of the solid is governed by Stokes flow, and melt is transported according to Darcy's law. However, many formulations of this coupled Stokes/Darcy flow break down in the limit of vanishing melt fraction, because in this case the system is mathematically degenerate. A common solution for this problem is introducing a cutoff for certain material properties or solution variables. However, regularising the equations in such a way generally means that the method becomes computationally expensive as soon as the melt fraction approaches zero in some part of the domain and/or that the Stokes equations are not recovered for vanishing melt fraction. Here, we present a new formulation of the equations for coupled Stokes/Darcy flow that addresses these shortcomings and allows it to compute large-scale 3-D magma/mantle dynamics simulations with extensive regions of zero melt fraction. By rescaling one of the solution variables, we ensure that one of the three equations in our system becomes an identity and the other two revert to the Stokes system. This allows us to split the domain in two parts: In mesh cells where melt is present, we solve the coupled Stokes/Darcy equations. In cells without melt, we solve the Stokes system as it is done for mantle convection without melt transport and constrain the remaining degrees of freedom. Hence, we do not spend any resources on solving additional equations if no melt is present, improving the solver performance substantially. We have implemented this formulation in the open source, adaptive mesh geodynamic modelling code ASPECT. Here, we derive our new formulation, demonstrate the correctness of our implementation in a number of benchmark cases, illustrate the improved performance compared to the three-field formulation used in earlier studies, and show 2-D and 3-D application cases in earth-like settings.

Preferred Platform: Oral Presentation

Student Presenter: N

CIG_04

Adaptive Multigrid Solvers for Stokes flow

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Mantle convection problems require the solution of Stokes problems in every time step to solve for velocity and pressure in the mantle. There are several difficulties associated with solving the linear systems arising from a finite element discretization: 1. highly localized features require adaptive mesh refinement for adequate resolution. 2. resulting linear systems are still very large (100+ million unknowns). 3. large viscosity jumps require robust solvers and discretizations. 4. fast solution and the size of the systems require large-scale parallel computing. We try to address this problem with a geometric multigrid method that works efficiently with adaptively refined meshes. This talk compares a number of solution approaches including matrix-free operator evaluation, saddle-point preconditioners, and monolithic Schwarz smoothers. The performance is compared to existing solution methods like algebraic multigrid.

Preferred Platform: Oral Presentation

Student Presenter: N

Toward Community Software Ecosystems for High-Performance Computational Science

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Software---crosscutting technology that connects advances in mathematics, computer science, and domain-specific science and engineering---is a cornerstone of long-term collaboration and scientific progress. As we leverage unprecedented high-performance computing resources to work toward predictive science, software complexity is increasing due to multiphysics and multiscale modeling, the coupling of simulations and data analytics, and the demand for greater reproducibility in the midst of disruptive architectural changes. Applications increasingly require the combined use of independent software packages, which have diverse sponsors, priorities, and processes for development and release. These challenges create the unique opportunity to improve how scientific software is designed, developed, and sustained---with explicit work toward scientific software ecosystems. This presentation will introduce the Extreme-scale Scientific Software Development Kit, or xSDK (<https://xsdk.info>), where community-defined policies are increasing the quality and interoperability across numerical libraries and application-specific packages. We will also discuss complementary efforts to increase scientific software productivity and sustainability, including work by a variety of international community groups and by the IDEAS scientific software productivity project (<https://ideas-productivity.org>).

Preferred Platform: Oral Presentation

Student Presenter: N

Progress and remaining challenges in incorporating detailed chemical kinetics models in simulations of reactive flows

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Simulations of reactive fluid flows, including combusting, geophysical, and astrophysical flows, rely on accurate and efficient methods for solving the stiff ordinary differential equations describing the finite-rate chemical kinetics. However, the size and complexity of these models frequently pose prohibitive computational costs, requiring strategies to reduce cost while retaining model fidelity. This talk will summarize the challenges of incorporating detailed, finite-rate chemistry in reactive-flow simulations, and describe complementary efforts by our group to solve them. First, I will discuss the challenges of using accurate, detailed models for chemistry in realistic simulations of reacting flows. In particular, the large sizes of chemical reaction models for the oxidation of liquid transportation fuels present significant computational difficulties for combustion modeling; in addition, the differential equations describing the evolution of these systems typically exhibit extreme stiffness. Similar problems arise in simulations of geophysical and astrophysical flows. Next, I will describe an array of complementary strategies for solving these challenges, including a suite of methods for reducing the size of these large models while retaining a high level of accuracy and predictability and new computational techniques for exploiting the massive parallelism of graphics processing units and other modern, many-core parallel processors. I will conclude with a summary of our progress, and discussions of remaining challenges.

Preferred Platform: Oral Presentation

Student Presenter: N

CIG_04

Best practices for sustainable and open research software in computational research

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Modern research in science and engineering relies heavily on software, but while academia uses citation to credit traditional research output, no such standard exists to acknowledge the effort that goes into software. In addition, written publications describing computational research, or any research that relies on computed results, cannot adequately describe the methodology of the associated work, but are only advertisements of it—sufficient scholarly output requires software to be released openly alongside traditional articles. Motivated both by credit for research software and reproducibility in computational research, this talk will discuss principles of software citation, venues for sharing and publication of research software, and best practices for reproducibility in computational research. In addition, strategies for ensuring sustainability of software projects will be shared.

Preferred Platform: Oral Presentation

Student Presenter: N

CIG_04

Present and Future of Earthquake Ground Motion Simulation

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Recent advances in computational modeling of earthquake processes indicate that the role of three-dimensional earthquake ground motion simulation will be increasingly important in various seismological and engineering applications. The push for higher frequencies and more realistic physics, however, pose significant challenges both at the physical and computer science levels. This talk reviews the present and future of computational earthquake ground motion simulation in light of recent and future advances in inelastic material modeling, intrinsic attenuation, material heterogeneities, coupling of wave propagation with the response of the built environment, verification, validation, and advantages drawn from the use of machine learning techniques and new computer architectures, as well as the challenges that lie ahead in these very areas.

Preferred Platform: Oral Presentation

Student Presenter: N

Advances in the geodynamic code ASPECT: Investigating compressibility approximations, modular boundary conditions, and flexible surface deformation

Rene Gassmoeller, Juliane Dannberg, Timo Heister, Wolfgang Bangerth

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The last years have seen a significant advancement in the evolution of geodynamic modeling, both in the size of performed models and complexity of modeled processes. Several driving factors have made this change possible: Increased availability of data, increasing availability of high-performance computing, improved numerical algorithms like linear solvers and preconditioners, and a better understanding of how to engineer and manage geodynamic software. In this contribution I will present software development strategies and applications using the mantle convection software ASPECT, which is developed as a modular, massively parallel, open-source code for the geodynamic community. In particular, I discuss techniques that allow different linear systems (equations describing different processes), solvers, and solver schemes to coexist in a single software. This allows direct comparisons between different methods and optimizations for particular applications. Using this modularity, I compare a number of approximations for the compressible Stokes equations and evaluate the limits of the commonly used anelastic liquid approximation, which is based on a reference-profile, in the presence of local temperature or density perturbations, such as caused by phase transitions or superadiabatic temperature gradients. Additionally, I will showcase how a modular software design allows us to easily build realistic geodynamic models with increasingly complex boundary conditions, and a freely deformable surface. These techniques allow models like small-scale visco-plastic crustal deformation with a free surface, instantaneous or long-term mantle convection with incompressible or compressible approximations, magma/mantle dynamics, and inner core convection to be realized in the same software package. Finally, I will discuss future plans for ASPECT, including the coupling with other software packages, and the verification of increasingly complex models.

Preferred Platform: Poster Presentation

Student Presenter: N

A new conceptualization of three-dimensional slab interactivity visualized with ShowEarthModel

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A global inspection of modern slab geometries indicates that slabs are discontinuous features with variable dip, depth, and sense of curvature. In this way, a two-dimensional paradigm for conceptualizing slab geometries over simplifies the problem and can lead to misconceptions in terms of process. Increasing access to digital data as well as advances in visualization algorithms now allow for a new conceptualization of modern subduction systems on Earth. Here we present sixteen movies that interrogate the modern slab geometries on Earth. The movies are a result of interactive 3D visualization sessions using the open source ShowEarthModel program. These movies provide a snapshot into the four-dimensional evolution of plate tectonics, by showing a series of virtual voyages through the Earth's interior. The 3D visualizations elucidate the manner in which slabs intersect and overlap, processes that occur in at least six of the Earth's major subduction zones. The high-resolution movies show that examining the modern subduction system in an interactive 3D framework with ShowEarthModel provides an improved conceptualization of the 3D morphology of slabs. Addressing the complex geometries of the subducted lithosphere raises questions, as well as places constraints on, outstanding questions of subduction dynamics including slab strength, mantle rheology, mantle flow rates, and plate-asthenosphere coupling. Conceptualizing a realistic 3D slab geometry framework in this way is of value to geologists, geodeticists, seismologists, volcanologists, sedimentologists, geochemists, as well as geodynamicists.

Preferred Platform: Poster Presentation

Student Presenter: N

**Slab dehydration and fluid migration beneath arc volcanoes using COMSOL
Multiphysics®**

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Understanding slab dehydration and fluid migration beneath the arc volcanoes is important because it allows us to understand characteristics of the arc volcanism such as migration of the volcano front, behaviors of the subducting slab and overlying plate as well as the global circulation of water and carbon. However, slab dehydration and fluid migration have not been broadly considered in the numerical modeling because of technical difficulties in the implementation of the relevant governing equations expressed as partial differential equations (PDEs). To minimize the technical difficulties and easier implementation of the slab dehydration and fluid migration, the COMSOL Multiphysics®, a commercial finite element package, is utilized. By modifying the implemented module of the Transport of Diluted Species (TDS) in the package, slab dehydration and fluid migration are successfully implemented in the 2-dimensional subduction model. As a preliminary study, the water solubility of the basalt for the subducted oceanic crust, reported from the laboratory experiment, is used to understand the dehydration style of the subducted oceanic crust in the mantle wedge. The model calculations show that most of the water of the oceanic crust is expelled beneath the corner of the mantle wedge (<100 km), which implies that the serpentinization of the overlying mantle wedge is a crucial key to transportation of the dehydrated water from the subducting slab to the deep mantle wedge. Implementation of the hydration and partial melting of the mantle wedge is undergoing and applied to both 2- and 3-dimensional subduction model.

Preferred Platform: Poster Presentation

Student Presenter: N

MeltMigrator: A MATLAB-based software for modeling three-dimensional melt migration and crustal thickness variations at mid-ocean ridges

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MeltMigrator is a MATLAB-based melt migration software developed to process three-dimensional mantle temperature and velocity data from user-supplied numerical models of mid-ocean ridges, calculate melt production and melt migration trajectories in the mantle, estimate melt flux along plate boundaries, and predict crustal thickness distribution on the seafloor.

MeltMigrator is also capable of calculating compositional evolution depending on the choice of petrologic melting model. Programmed in modules, MeltMigrator is highly customizable and can be expanded to a wide range of applications. We have applied it to complex mid-ocean ridge model settings, including transform faults, oblique segments, ridge migration, asymmetrical spreading, background mantle flow, and ridge-plume interaction. In this technical report, we include an example application to a segmented mid-ocean ridge. MeltMigrator is available from GitHub and the University of Maryland Geodynamics Group website.

Preferred Platform: Poster Presentation

Student Presenter: N

CIG_04

Efficient and Practical Newton Solvers for Nonlinear Stokes Systems in Geodynamic Problems

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The most commonly used method by the geodynamical community for solving non-linear equations is the Picard fixed-point iteration. However, the Newton method has recently gained interest within this community because it formally leads to quadratic convergence close to the solution as compared to the global linear convergence of the Picard iteration. In mantle dynamics, a blend of pressure and strain-rate dependent visco-plastic rheologies is often used. While for power-law rheologies the Jacobian is guaranteed to be Symmetric Positive Definite (SPD), for more complex rheologies, especially in combination with compressible models, the Jacobian may become non-SPD. Here we present a new method for efficiently enforce the Jacobian to be SPD, necessary for our current highly efficient Stokes solvers, with a minimum loss in convergence rate.

Preferred Platform: Poster Presentation

Student Presenter: n

CSAFM_01: Land-atmosphere interactions and fluxes in a changing climate and environment

Conveners: Manuel Helbig¹, Oliver Sonnentag², Laxmi Sushami³, Aaron Glenn⁴, Andrew VanderZaag⁵, Paul Moore¹

Co-chairs: Manuel Helbig, Aaron Glenn, Andrew VanderZaag, Paul Moore

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Reduction in global area burned and wildfire emissions since 1930s enhances carbon uptake by land

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The terrestrial biosphere currently absorbs about 30% of anthropogenic CO₂ emissions. This carbon uptake over land results primarily from vegetation's response to increasing atmospheric CO₂ but other factors also play a role. Here we show that since the 1930s increasing population densities and cropland area have decreased global area burned, consistent with the charcoal record and recent satellite-based observations. The associated reduced wildfire emissions from increases in cropland area do not enhance carbon uptake since natural vegetation that is spared burning was deforested anyway. However, reduction in fire CO₂ emissions due to fire suppression and landscape fragmentation associated with increases in population density is calculated to enhance land carbon uptake by 0.13 Pg C yr⁻¹, or ~19% of the global land carbon uptake (0.7±0.6 Pg C yr⁻¹), for the 1960-2009 period. These results identify reduction in global wildfire CO₂ emissions as yet another mechanism that is currently enhancing carbon uptake over land.

Platform: Oral Presentation

Student presentation: No

Improving Estimates of Cropland Evapotranspiration using the Penman-Monteith Equation at Two Southern Manitoba Sites

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Cropland evapotranspiration (ET) can be estimated using the Penman-Monteith equation with crop coefficient values as an approach that requires only weather station measurements as model inputs. Manipulating the Penman-Monteith equation to better represent southern Manitoba agroecosystems could increase the accuracy of ET determination across the province. We hypothesized that incorporating direct measurements of net radiation, developing crop coefficients using in-field weekly leaf area index, crop staging and crop height values and integrating water stress coefficients would improve the Penman-Monteith equation's accuracy in comparison to direct measurements using the eddy covariance method. Comparisons were done in spring wheat (*Triticum aestivum*) near Carberry, Manitoba and in soybeans (*Glycine max*) near Miami, Manitoba. Micrometeorological equipment were used to collect data needed to calculate ET with the eddy covariance method, as well as collect meteorological values used to determine reference evapotranspiration through the Penman-Monteith equation. Crop coefficient values calculated from the FAO-56 method and basal coefficient values generated from crop height, staging and leaf area index were used in combination with reference ET to estimate actual evapotranspiration. There was good agreement between estimated and measured ET when vegetation was mature but there were large discrepancies during vegetative growth and senescence stages. Incorporating direct net radiation measurements made minimal improvements in the accuracy of the Penman-Monteith equation. Further results will be explored regarding improvements to the equation through creating field-specific crop coefficients and incorporating a water-stress coefficient. The ability to generate accurate estimated ET is important as it can help simplify evapotranspiration data collection across various agroecosystems, which can help map water movement throughout Manitoba in greater detail.

Preferred Platform: Oral Presentation

Student Presenter: Y

Multi-year comparison of nitrous oxide emissions measured by eddy-covariance and flux-gradient methods

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Agricultural nitrous oxide emissions occur as pulses at short intervals with the timing and magnitude dependent on management, soil, and climatic conditions. The multi-plot flux gradient (FG-M) method provides side-by-side comparisons of total N₂O emissions from separate treatments under similar climatic and soil conditions using field-scale plots with one gas analyzer. Few comparisons exist to evaluate FG-M N₂O flux measurements against EC measurements. The FG-M technique has been used to measure N₂O emissions from four 4-ha plots in Elora, Ontario. In 2015, an EC system was installed in one plot to simultaneously measure N₂O fluxes using a TE cooled tunable diode laser absorption spectrometer (Campbell Scientific Inc. TGA200A). The FG-M intakes were located near the centre of each plot. In spring of 2017, a new low-power (30 W) N₂O FG system (FG-LP) and a separate EC-CO₂ flux measurement system was installed at the same location and height as the N₂O-EC system. The FG systems simultaneously measured CO₂ fluxes. This allowed for a comparison between EC, FG-M, and FG-LP N₂O and CO₂ flux measurements. N₂O and CO₂ fluxes measured by the FG-LP system correlated well with the EC measurements ($r^2 = 0.96$, slope = 1.13 N₂O, $r^2 = 0.91$, slope = 1.05 CO₂). The FG-M N₂O fluxes correlated with the EC fluxes ($r^2 = 0.85$) but magnitudes were ~70% lower than the EC and FG-LP fluxes. However, CO₂ fluxes corresponded to those of the EC system for the exact same time period ($r^2 = 0.80$, slope = 1.05). The good agreement between the co-located FG-LP and EC system for both N₂O and CO₂, as well as that of CO₂ for the FG-M system, indicates that the discrepancy between the FG-M and EC fluxes are not due to the FG method but differences in footprint. Soil analysis confirmed lower nitrate concentrations within the footprint of the FG-M intake. This exemplifies the greater degree of spatial heterogeneity of soil N₂O emissions as compared to CO₂.

Preferred Platform: Oral Presentation

Student Presenter: N

Alternative plant strategies influence the relationship between plant traits and net primary productivity

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Net primary productivity (NPP) is a measure of how much carbon (C) is allocated to growth in a given ecosystem and is a key parameter in vegetation and climate models. Improving estimates of NPP is critical to understanding and predicting future C stocks, especially in light of the pressing need to predict atmospheric carbon dioxide concentrations. However, it is challenging to measure NPP over large spatial and temporal scales. One approach is to estimate NPP using continuous plant traits that relate to differences in NPP. Despite a strong theoretical framework, few empirical data quantitatively link plant traits to NPP directly. We assessed the ability of 15 traits to predict NPP in 30 herbaceous *Asclepias* species grown under common garden. Leaf area and plant height explained the majority of variation in NPP ($R^2 = 0.49, 0.25$, respectively). Leaf economic spectrum traits performed poorly and most trait-NPP relationships were context dependent based on differences among plant strategies. Species grouped into four distinct strategies defined by biomass allocation, plant size and economic traits. Some commonly used traits have limited general predictive ability in part because similar NPP can be achieved by alternative plant strategies based on leaf-level and whole-plant tradeoffs. We suggest a way forward to improve trait-based estimates of NPP in vegetation and climate models under current and future scenarios.

Preferred Platform: Oral Presentation

Student Presenter: Y

Modelling local scale sensible and latent heat advection contributions to snowmelt

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Local-scale advection of energy from warm snow-free surfaces to cold snowcovered surfaces is an important component of the energy balance during snowcover depletion. Unfortunately, this process is difficult to quantify in one-dimensional snowmelt models and the latent heat advection process has been neglected to date. A simple sensible and latent heat advection model is proposed here to explicitly represent areal average advection energy fluxes that contribute to snowmelt as snowcover becomes heterogeneous. Established scaling properties of snow patch area distribution and lengths, necessary to translate patch scale advection flux parametrisations to areal average fluxes, were also re-evaluated with snowcovered area observations from unmanned aerial vehicle imagery. The proposed model compares well with observations of latent and sensible heat advection which provides confidence in the process parameterizations and the assumptions applied. Modelling demonstrates that dry snow-free surfaces are associated with negative latent heat advection fluxes, which compensate for positive sensible heat advection fluxes and therefore limited the net influence of advection on snowmelt. In contrast, wet snow-free surfaces result in a positive latent heat advection flux to snow, which enhances the net advection contributions to snowmelt. The increased net advection flux from wet surfaces typically develops towards the end of snowmelt as snowcovered area declines. This compensates for declining areal average melt energy from vertical fluxes with snowcovered area. The proposed model provides an avenue to improve snowmelt understanding and predictions as it can be readily incorporated into existing one-dimensional snowmelt hydrology and land surface scheme models.

Preferred Platform: Oral Presentation

Student Presenter: Y

Comparison of Scintillometer and Eddy Covariance Measurements of Sensible and Latent Heat Fluxes over a Humid Boreal Forested Valley

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Boreal forest covers a third of Canada surface and accounts for 75% of all its forests. Over this type of environment, most of the previous measurements of surface-atmosphere water and energy fluxes are obtained with the eddy covariance method. While being very reliable, the method has a local scale footprint of a few hectares. This can be problematic for climate modelers looking for validation data on tiles of few km², especially in the heterogeneous boreal biome. Scintillometry can serve as a link between local and larger scales, namely by evaluating turbulent fluxes with the scintillations of light beams between transmitters and receivers separated by 1-10 km. This study presents a comparison of eddy covariance and scintillometer fluxes, for the first time over a boreal-forested shallow valley. The field site is part of the Montmorency Forest, 70 km north of Quebec City, Canada. Scintillometer transmitters and receivers are installed on top of the ridges enclosing a 100-m deep valley, making the light-beam path 1.35 km long. The two main wind directions are an up and down-valley flow crossing the beam. Up-valley vegetation is mostly homogeneous (balsam firs 6-10 m tall), while the down-valley area displays more heterogeneities (trees 0-20 m tall). The devices were deployed intermittently from August to October 2017. In addition, a 15-m eddy covariance tower is located 100 m up-valley of the measurement path. Fluxes measured with both methods are compared when footprints overlap. Preliminary results show that scintillometer fluxes are generally higher than those obtained with the eddy covariance setup, with a much better correlation between methods with latent heat fluxes. Recorded scintillometer fluxes from the heterogeneous forest are higher than those from the homogeneous side, but more analyses are needed to confirm this result. Ultimately, this study aims at bridging the spatial scale gap between eddy covariance observations and climate models.

Preferred Platform: Oral Presentation

Student Presenter: Y

The effects of peat bog restoration on carbon uptake – remote sensing as a monitoring tool.

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Peatlands are an important part of the earth's carbon cycle, comprising approximately a third of the global terrestrial carbon store. However, peatlands are sensitive to climatic change and human mismanagement, and many are now degraded and acting as carbon sources. Restoration work is being undertaken at many sites around the world, but monitoring the success of these schemes can be difficult and costly using traditional methods. A landscape-scale alternative is to use satellite data in order to assess the condition of peatlands and estimate carbon fluxes. This work focuses on study sites in Northern Scotland, where parts of the largest blanket bog in Europe are being restored from forest plantations. A combination of laboratory and fieldwork has been used to assess the Net Ecosystem Exchange (NEE), Gross Primary Productivity (GPP) and respiration of peatland sites in different conditions, and the climatic vulnerability of key peat-forming Sphagnum species. The results from these studies have been compared with spectral data in order to evaluate the extent to which remote sensing can function as a source of information for peatland health and carbon flux models. This work considers particularly the effects of scale in calculating peatland carbon flux. Flux data includes chamber and eddy covariance measurements of carbon dioxide, and radiometric observations include both handheld spectroradiometer results and satellite images. Results suggest that despite the small-scale heterogeneity and unique ecosystem factors in blanket bogs, remote sensing can be a useful tool in monitoring peatland health and carbon sequestration. In particular, this study gives unique insights into the relationships between peatland vegetation, carbon flux and spectral reflectance.

Preferred Platform: Oral Presentation

Student Presenter: Y

Future projections of rain-on-snow events and their impact on surface hydrology in the Fraser River basin, British Columbia.

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We evaluate Rain on Snow (ROS) events and its characteristics for the 1970- 1999 and 2070-2099 periods using GCMs (RCP 8.5 emission pathway) driven Variable Infiltration Capacity (VIC) hydrological model output in Fraser River Basin, BC, Canada. The downscaled GCMs data analyzed with gridded observed data set to check the consistency of model data. The comparison indicated that the model data represented rationally the real conditions. Analysis of ROS events for scenario period predicts relatedly higher compared to historical ROS events. The ROS event is expected to increase overall basin, however much more in coastal and rocky mountain regions compare to interior plateau region. The most notable variability of ROS is different trend in each sub-basin scale. The overall increasing trend of ROS events in future scenario is expected to increase winter runoff in Fraser river basin which has several implications in ecological economic perspective.

Preferred Platform: Oral Presentation

Student Presenter: Y

Evaluating evaporative fluxes in complex mountain terrain

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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 kite-sonde, 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.

Preferred Platform: Oral Presentation

Student Presenter: Y

Acidification of Liquid Dairy Manure for Reduction of GHG Emissions

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Liquid dairy manure storages are hot spots of methane (CH₄), nitrous oxide (N₂O) and ammonia (NH₃) emissions. Both CH₄ and N₂O are greenhouse gases (GHG), while NH₃ is an indirect source of N₂O, and a risk to human health. Manure acidification has been used for reducing ammonia emissions for various livestock manure types, however, its potential for overall GHG reduction from liquid dairy manure is unclear. We expected both NH₃ and CH₄ to be reduced by acidification. Our study compared control dairy manure (pH 7.4) to manure acidified on June 26 with 70% sulphuric acid to pH 6 (2.4 mL acid/L manure) and pH 6.5 (1.4 mL acid/L manure). We used a system of replicated meso-scale manure storage tanks (6.6m²) enclosed by steady-state chambers. Both CH₄ and N₂O were continuously measured from June through December (2017) using tunable diode laser trace gas analyzers. Ammonia emissions were measured 3x per week for 24 hr using acid traps. On a CO₂-eq basis, the pH 6 treatment reduced total GHG emissions by 89%, while the pH 6.5 treatment reduced emissions by 86%, relative to untreated manure. Total GHG emission reductions were primarily due to decreased CH₄ emissions. Ammonia emissions were reduced 49% by pH 6 treatment and 38% by pH 6.5 treatments. On a cost-benefit basis, reducing total GHG emissions by an extra 3%, by acidifying to pH 6 instead of pH 6.5, would cost nearly twice as much (\$4.5/m³ manure vs \$2.6/m³ manure). More research is necessary to make acidification an accessible treatment for farmers, by optimizing dosage for best cost and long-term treatment effects. More field and laboratory research will help describe the manure buffering capacity and emissions reductions, to calculate best approaches for treating farm-scale liquid dairy manure tanks.

Preferred Platform: Oral Presentation

Student Presenter: Y

A Decade of Nitrous Oxide Flux Measurements for Annual and Perennial Crop Rotations on the Canadian Prairies

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The magnitude and timing of nitrous oxide (N₂O) emissions from cropping systems depend on cropping and management decisions as well as soil and meteorological conditions. Here we report N₂O emissions from two cropping systems in southern Manitoba, Canada, for the years 2006-2016. The study site soil is a poorly drained clay, high in soil organic matter (3.2 g organic C kg⁻¹). A continuous annual cropping system was compared to a cropping system that included a 4-year perennial phase. N₂O emissions and NEP were determined using the flux-gradient approach with N₂O and CO₂ gradients measured with a tunable-diode laser analyser and momentum similarity theory and 3-D sonic anemometer-thermometer measurements to estimate transfer coefficients. Cumulative N₂O emissions among four adjacent 4-ha fields over the 10 years varied from 0.3 to 28 kg N₂O-N ha⁻¹ y⁻¹, depending on annual crop (corn, faba, spring wheat, barley, rapeseed, soybean) and environmental conditions. Inclusion of the 4-year perennial alfalfa/grass phase lowered the range in emissions being 0.2 to 2 kg N₂O-N ha⁻¹ y⁻¹. Emissions with the annual crops mostly occurred (>70%) in spring following planting and fertilizer N addition, whereas, emissions were equally distributed between soil thaw period in April, spring, and the remainder of year. Meteorological and associated soil conditions, management (agronomic practices), NEP and partitioned CO₂ exchanges (GPP, respiration) and harvest removals on thaw, and spring N₂O emissions were assessed using univariate and multivariate statistical approaches. Soil nitrate concentrations mostly influenced N₂O fluxes at thaw. Consistent occurrence of late spring rains induced fluxes from applied fertilizer N. In conclusion, management practices such as N fixing crops (alfalfa/grass, faba, soybean) reduced emissions while nitrate accumulation of fertilizer applied N and rainfall increased emissions from non-N fixing crops.

Preferred Platform: Oral Presentation

Student Presenter: N

The wind field in a cattle feedlot: measurements and simulations

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In the context of methane flux measurements, transects of mean wind speed were measured across an empty pen (68 m x 60 m) situated on the outer edge of a large (circa. 1 km by 1 km) cattle feedlot. Aggregated by mean wind direction and stratification, these observations revealed that fractional variation of wind speed across the pen (at constant height) exceeded 400%, primarily due to shelter in the wakes of tall (3 m), low porosity (25%) boundary fences that formed a network delineating the pens. Micrometeorological measurements of feedlot gas emissions would therefore potentially be subject to error or misinterpretation, which motivates an investigation of the feasibility of estimating the wind field, so as to be able to compensate (if appropriate) for its non-uniformity. The pattern of mean wind speed (S) and turbulent kinetic energy (k) in the feedlot was simulated using a three-dimensional RANS (Reynolds-averaged Navier Stokes) model ("ASL3D"), adopting periodic lateral boundary conditions and a simple eddy viscosity closure. Fences were represented by imposing localized momentum sinks to reduce the wind component normal to their surface(s), and, additionally, nulling the wind component tangential to the fences ("no-slip"). On the condition that this no-slip condition was imposed, computed wind transects proved in excellent agreement with those measured under near-neutral stratification, even though the computed and measured transects of turbulent kinetic energy differed markedly. Calculations with different choices for domain size indicate that lateral boundaries need not be placed far beyond the fences bounding the test pen.

Preferred Platform: Oral Presentation

Student Presenter: N

Upscaling CH₄ Fluxes Using High-Resolution Imagery in Arctic Tundra Ecosystems

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Arctic tundra ecosystems are a major source of methane (CH₄), the variability of which is affected by local environmental and climatic factors, such as water table depth, microtopography, and the spatial heterogeneity of the vegetation communities present. There is a disconnect between the measurement scales for CH₄ fluxes, which can be measured with chambers at one-meter resolution and eddy covariance towers at 100–1000 m, whereas model estimates are typically made at the ~100 km scale. Therefore, it is critical to upscale site level measurements to the larger scale for model comparison. As vegetation has a critical role in explaining the variability of CH₄ fluxes across the tundra landscape, we tested whether remotely-sensed maps of vegetation could be used to upscale fluxes to larger scales. The objectives of this study are to compare four different methods for mapping and two methods for upscaling plot-level CH₄ emissions to the measurements from EC towers. We show that linear discriminant analysis (LDA) provides the most accurate representation of the tundra vegetation within the EC tower footprints (classification accuracies of between 65% and 88%). The upscaled CH₄ emissions using the areal fraction of the vegetation communities showed a positive correlation (between 0.57 and 0.81) with EC tower measurements, irrespective of the mapping method. The area-weighted footprint model outperformed the simple area-weighted method, achieving a correlation of 0.88 when using the vegetation map produced with the LDA classifier. These results suggest that the high spatial heterogeneity of the tundra vegetation has a strong impact on the flux, and variation indicates the potential impact of environmental or climatic parameters on the fluxes. Nonetheless, assimilating remotely-sensed vegetation maps of tundra in a footprint model was successful in upscaling fluxes across scales.

Preferred Platform: Poster Presentation

Student Presenter: N

The effects of forest sheltering on peatland surface level turbulent processes in the Boreal Plains, Alberta, Canada

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Peatlands comprise approximately 50% of the total landscape of the Western Boreal Forest, including the sub-humid Boreal Plains (BP) zone. The BP experiences persistent water deficit conditions, prohibiting anaerobic conditions, which has the potential to increase decomposition, transforming the peatlands from carbon sinks to carbon sources. With evapotranspiration (ET) being the dominant source of water loss in the BP, it is necessary to understand the dynamics and controls on ET within these wetlands. Peatlands often experience turbulent sheltering from their surrounding upland forests, which results in spatially variable surface-atmosphere exchanges of momentum, heat, and moisture, produced by zones of flow separation which suppresses the transport of such scalars. Understanding the dynamics between peatland and upland forests will allow us to assess the atmospheric stresses on peatlands under future climatic and land use scenarios. The use of the Regional Atmospheric Forest Large Eddy Simulation (RAFLES) allows for various wetland and upland forest configurations to be simulated at a high temporal and spatial resolution. Results have shown that wetlands with the same area and shape, but a different orientation to the dominant wind direction experience significantly different surface level atmospheric stresses. Furthermore, larger surface roughness lengths increase the drag exerted by the canopy, which reduces flow recirculation within sheltered regions.

Preferred Platform: Poster Presentation

Student Presenter: Y

CSAFM_01

Improving CLM4.5 Simulations of Land–Atmosphere Exchange during Freeze–Thaw Processes on the Tibetan Plateau

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Soil has an important effect on land–atmosphere interactions. In this study, an improved soil parameterization scheme that considers gravel and organic matter was introduced into CLM4.5 (Community Land Model). The ability of the model to simultaneously simulate the duration of freeze–thaw periods, soil temperature, soil moisture, and surface energy during freeze–thaw processes was validated on the Tibetan Plateau. The results indicated that: (1) the new parameterization performed better in simulating the duration of the frozen, thawing, unfrozen, and freezing periods; (2) the soil thermal conductivity values were decreased; (3) the new parameterization improved soil temperature simulation and effectively decreased cold biases; (4) the new parameterization scheme effectively decreased the dry biases of soil liquid water content; and (5) the net radiation, latent heat flux, and soil surface heat flux were much improved by the new organic matter and thermal conductivity parameterization.

Preferred Platform: Poster Presentation

Student Presenter: N

Assessing the influence of vegetation cover on evapotranspiration atop bare waste rock surfaces, Elk Valley, British Columbia

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Surface mining in Elk Valley, British Columbia involves the removal of upper levels of vegetation, soil and rock to access underlying coal. The waste rock is placed into adjacent valleys, frequently burying headwater streams. Due to their coarse texture, these waste rock piles increase infiltration and percolation, leading to increased solute transport through the overburden and into downstream surface water. It is hypothesized that through reclamation, revegetation will enhance evapotranspiration (ET) and reduce percolation through the waste rock. This study examined the surface-atmosphere water and energy budgets using eddy covariance towers atop three waste rock surfaces with different vegetation types: 1) an ~25 year old ~5 m tall mixed coniferous forest, 2) a reclaimed grass cover and 3) a bare waste rock surface. Measurements were taken from late July to October in 2012 and from May to late October in 2013 and 2014. Soil moisture and matric suction were measured to 1 m at several locations per site. Sapflow velocity measurements at the forested site were used to partition transpiration and scale overall ET. In all years, ET rates were greatest at the forested site, followed by the grass cover and lowest at the bare waste rock site, with seasonal totals exceeding up to 200 mm greater at the forest site compared to the waste rock. At the vegetated sites, climate was the main driver of ET, with high radiation, and warm and dry conditions enhancing fluxes. Peak ET at these sites corresponded with peak growing season, with vegetation increasing transpiration and rainfall interception. In contrast, at the bare site, ET was weakly related to climate. ET rates briefly increased during periods following precipitation events when near surface moisture increased before rapidly draining. Results suggest increased vegetative cover should be incorporated into mine reclamation plans to enhance ET rates and vertical exchange and limit percolation through waste rock.

Preferred Platform: Poster Presentation

Student Presenter: Y

Comparison of Different Modelling Approaches to Predict Ecosystem CO₂ Fluxes from Chamber-Based Measurements

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CO₂ uptake through photosynthesis and CO₂ release through ecosystem respiration are processes fundamental in determining C balances of terrestrial ecosystems. Chamber-based measurement systems are widely used to ascertain rates of net ecosystem exchange and ecosystem respiration. However, choices made in the processing pipeline from raw data to annual C budgets can lead to differences in the ultimate result. R is an open source statistical computing software and can be used to create reproducible research. This study compares an expert-based C-budgeting approach using TableCurve with two different R-based methodologies (Hoffmann et al. 2015, Jurasinski et al. 2014), which are both freely available on the internet. Moreover, water vapor dilution in the evolving CO₂ molar fraction may lead to significant overestimation of photosynthesis in the flux data. Therefore, a water vapor dilution correction is tested as well. Differences in modelling approaches are exemplified on a dataset of 38 months of manual dynamic flow-through chamber measurements at a cultivated fen. Effects of water vapor dilution correction are studied on a 14-month subset of these data.

Preferred Platform: Poster Presentation

Student Presenter: Y

Methane production from liquid dairy manure incubated with an acidified inoculum at 17, 20, and 23⁰ C.

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Studies have shown that acidification of liquid dairy manure reduces methane (CH₄) emissions. However, it is not known if the leftover acidified manure in tanks acts as an effective inoculum, or if CH₄ emissions continue to be reduced during the following storage period even if acid is not added again. In order to assess long-term effects, we used 6-month old acidified manure as an inoculant for anaerobic lab incubation of liquid dairy manure. The control used 6-month old untreated manure from the same farm. Gas production was measured using a liquid displacement manometer, while CH₄ concentration was measured using gas chromatography. Incubations lasted for 5 months at 17, 20, and 23⁰ C, which are representative of liquid manure temperatures during the summer in Canada. The control treatments produced 3.1, 3.4, and 4.2 L CH₄ L⁻¹ manure at 17, 20, and 23⁰ C, respectively, while the acidified inoculant treatment produced 0.02, 0.03, and 2.06 L CH₄ L⁻¹ manure, respectively. This shows the benefit of acidifying manure was 99% CH₄ reduction at 17 and 20⁰ C, and 51% at 23⁰ C. Results suggest that acidification could have long-term treatment effects, by reducing the inoculating effect of old manure the following year. This could cut overall cost of on-farm manure acidification and make it an accessible treatment technology.

Preferred Platform: Poster Presentation

Student Presenter: y

CSAFM_02: Understanding past, present and future effects of climate on agriculture, forestry and water resources

Conveners: Aston Chipanshi and Manasah Mkhabela

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The Relationship between Climate Variability and Vegetation Dynamic in Upper Stream of Heilongjiang (Amur) River, northeast Asia.

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In cold and arid region of upper Heilongjiang (Amur) river basin (UHAR), the variation in vegetation dynamics could be influenced by both temperature and precipitation. Long term (1982-2013) climatic and vegetation dynamic datasets were collected from Climatic Research Unit (CRU) and Global Inventory Monitoring and Modeling System (GIMMS). Time series and partial correlation analyses were conducted to reveal the trend and dominant factor that controlling the vegetation dynamic. Study results show that (1) Annual mean air temperature (TMP) has increased by 0.135 oC per decade ($P=0.32$) and precipitation (PPT) has declined by -1.52 mm per decade ($P=0.15$). A significant changing point at the year 2000 in PPT time series was detected by Mann-Whitney-Pettit test. From 1982 to 2000, PPT had decreased with a slope of -0.89 mm/10a ($P=0.07$). From 2001 to 2013, PPT had greatly increased with a slope of 7.73 mm per decade ($P=0.02$). (2) Annual NDVI and NDVI above 2.0 (NDVI_2.0, representing the growing period of vegetation) remain nearly unchanged during the recent 3 decades. From 1982 to 2000, NDVI and NDVI_2.0 had increased 5.53% and 1.42% respectively. From 2001 to 2013, NDVI and NDVI_2.0 had increased 2.80% and 10.51%. The growing season length (GSL, estimated by TIMESAT) has extended with a slope of 4.88 day per decade ($P=0.02$). (3) NDVI has significant correlation with PPT ($P=0.04$), and the GSL has significant person correlation with TMX ($P=0.04$). Partial correlation shows that NDVI and NDVI_2.0 have higher correlation coefficient with PPT ($P<0.05$) and significant negative partial correlation with TMP ($P=0.02$). We concluded that precipitation is the primary factor that dominates the vegetation dynamic. And the increased temperature extended the growing season length. Further estimation on water loss, caused by the prolonged duration of plant transpiration, is needed.

Preferred Platform: Oral Presentation

Student Presenter: N

Monitoring Change in Earth Observation based Vegetation Condition in Response to Variable Climate for Improved Yield Forecasting

Catherine Champagne, Yinsuo Zhang, Aston Chipanshi, Andrew Davidson, Jiangui Liu, Monica Varga

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Crop condition information from earth observation satellites has been used as a tool to track the impacts of variable climate for decades, primarily using vegetation indices such as the Normalized Difference Vegetation Index (NDVI). NDVI has been shown to be well correlated with crop yields at the regional level (Mkhabela et al., 2011) and it has been used to operationally forecast crop yields within the Canadian Crop Yield Forecast (CCYF) system in combination with meteorological indices (Chipanshi et al., 2015). This previous work has indicated that the magnitude of NDVI is most predictive of crop yields at its peak value (from late July to early August) and it explains the variability in crop yield more in the semi-arid regions than in the more humid regions of Canada. To improve the efficacy of NDVI as a predictor in crop yield models requires greater understanding of how NDVI reacts to both variability in climate and yield, and how these relationships influence predictive models at different spatial and temporal scales. Statistically based models are sensitive to the record length of data sets. Newer sensors such as MODIS provide NDVI data at higher spatial resolutions than older sensors such as AVHRR, but there are tradeoffs since newer sensors have shorter record lengths and may lead to less robust predictive models. There are also differences in the magnitude of NDVI between the two sensors, which may lead to differences in the sensitivity to crop yields from year to year and from crop to crop. We examined differences in NDVI at MODIS and AVHRR for predicting crop yields of major crops in Canada, investigated why these differences are occurring, and explored how NDVI may be better utilized in crop prediction. This work will provide preliminary results on how NDVI varies with variable weather conditions in Canadian agricultural regions, and how this relationship could be exploited to improve the accuracy of crop yield forecasts.

Preferred Platform: Oral Presentation

Student Presenter: N

Crop Metrics: An application for understanding crop and climate interactions

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In an attempt to address abiotic and biotic risks on crop production proactively, a Crop Metrics application was built to communicate crop health, yield and production outlooks as well as the associated risks ahead of harvesting for Canada's major economic crops such as wheat, barley, canola and soybean. The application was tested (using hands on training) with the potential users including Statistics Canada who have the mandate to report official crop statistics across Canada, Market and Industry Branch (MISB) responsible for conducting market intelligence for Canadian commodities and Policy and Programs advisors responsible for implementing specific policies and programs in response to identified risks and hazards. In this presentation/demonstration, work flows and a robust interactive and interpretive online application which integrates complex data sets and models from climate, soil and plant sciences will be provided. The goal of the crop metrics application is to empower users to experiment and ask "what if questions" via the interactive Graphical User interface (GUI) portal so that evolving uncertainties under the present climatic conditions and going into the future can be addressed.

Preferred Platform: Oral Presentation

Student Presenter: N

Weather and Climate Extremes on the Canadian Prairies: An Assessment with a Focus on Grain Production

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The Canadian prairies are Canada's granaries, producing up to 75 million tons of grain (primarily wheat, barley, and oats) and oilseeds (primarily canola) during the summer months of June to August. Canada is a major grain exporting country; exports have a market value of about 50 billion Cdn dollars. The Canadian prairie agricultural industry is a major socio-economic activity for western Canada, employing thousands in farming communities and in other industries such as transportation on a year-round basis. A good grain harvest in a given year depends critically on various summer weather and climate extremes which can adversely or favorably impact grain yield and quality. Typical among such extremes that can impact crop yield and quality are: extended drought accompanied by heat; wet and cool summers; and frosts during sowing period (late May to early June) and during ripening (August) and the harvest period (late August to mid-October).

This paper presents a number of examples of how extreme weather is implicated in grain production and quality estimates and annual exports. The paper analyzes some of the weather and climate extremes and their linkages to large-scale atmosphere-ocean circulation patterns. Among some of the important large-scale parameters that impact prairie summer weather are: the ENSO (El Nino-Southern Oscillation) phase in the equatorial Pacific, the MJO (Madden-Julian Oscillation in the eastern tropical latitude) and the PNA (Pacific North American) atmospheric flow pattern. Also detected is the impact of solar variability as identified by a geomagnetic index called the AP index (averaged planetary index).

Preferred Platform: Oral Presentation

Student Presenter: N

Agricultural Vulnerability and Adaptation to Climate Change: Emulating Crop Model Simulations

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Global gridded crop models (GGCMs) are the workhorse of assessments of the agricultural impacts of climate change. Yet the changes in crop yields projected by different models in response to the same meteorological forcing can differ substantially. We build on earlier research (Mistry et al., 2017) to elucidate the origins and implications of this divergence, both among GGCMs and within individual GGCM's historical and future simulated yield responses to temperature and precipitation. We use econometric models developed by the empirical climate change impacts literature to statistically characterize the responses of rainfed maize, rice, wheat, and soybean yields simulated by five GGCMs over three epochs: history (1972-2004), mid-century (2033-2065), and end-of-century (2067-2099). The resulting reduced-form emulators of yield response show that, relative to the historical period, future adverse sensitivity to high temperature (27°C) days is attenuated, while sensitivity to low precipitation (5 mm) days is amplified—shifts that we go on to attribute to different adaptation mechanisms within GGCMs. Our emulator approach holds considerable potential as a diagnostic methodology to elucidate uncertainties in the processes simulated by GGCMs, and to support the development of climate change impact inter-comparison exercises within the integrated assessment modelling community.

Preferred Platform: Oral Presentation

Student Presenter: N

Application of Temperature to Augment Precipitation Projections in Ontario

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As Ontario's climate changes, it is important to quantify the impact on infrastructure. A recent Ontario Ministry of Transportation (MTO) interpolation project quantified small trends of change ranging from approximately -0.5% to 2.0% per decade in rainfall intensity for Ontario locations between 1960 and 2010. The identification of historic trends helped refine current extremes and allowed the extrapolation of these trends to estimate future Intensity-Duration-Frequency (IDF) curve parameters in the MTO's IDF curve lookup tool. Current research, sponsored by Ontario's Ministry of the Environment and Climate Change (MOECC) with MTO support, explores a possible improvement for precipitation estimates by using thermodynamic parameters and state variables. The MOECC research focused on the correlation between historical temperature and precipitation. This enables the incorporation of temperature projections from different GCMs and their climate change scenarios. The MOECC research uses the historic temperatures in the climate change scenarios, correlates them with historic precipitation records, and creates probabilistic extreme rainfall projections for the selected Coupled Model Inter-comparison Project Phase 5 (CMIP5) climate change scenarios. This flexibility reflects the uncertainty in future climatic characteristics, and allows engineers and planners to identify the range of scenarios which are most appropriate for their needs. The results of the MOECC research are compared to historical rainfall data and other projections of extreme precipitation to determine the viability of the techniques.

Preferred Platform: Poster Presentation

Student Presenter: No

Climate change and the provision of rangeland ecosystem services in Alberta, Canada

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Climate change is anticipated to have wide-ranging effects on the provision of ecosystem services (ES) and consequently on the communities, and industries that rely on those services. Understanding these impacts and associated uncertainties, is therefore critical for long-term social, environmental, and economic planning. Using a multi-variable calibration approach, we developed nine regional-scale organic carbon dynamic models for consistent assessments of two main carbon-related ES of soil organic carbon storage (SOC) and aboveground biomass production (AGB) across Alberta's native grasslands (6.5 million hectares). The models were then used to assess impacts of recent, and future climate change (nine global and 10 regional climate models under two emission scenarios) on the provision of these two services and the uncertainties associated with these predictions.

Based on our preliminary analysis, the simulated response of SOC and AGB to recent and future climate change varied among climate models and scenarios. In general, the simulation results indicated reductions in SOC under most of the climate models, whereas AGB increased or remained stable in response to both recent and projected future climate change. However, predicted changes in SOC and AGB under different climate change model and scenarios varied considerably across the grassland regions. This suggests climate change risks, and adaptive strategies to maintain the provision of these services under a changing climate will be region-specific. We will use the knowledge and tools developed through this research to predict climate change-driven risks and opportunities for related industries (e.g., beef industry), as well as to identify alternative land management scenarios that might mitigate potential negative impacts of climate change on the provision of multiple rangeland ES.

Platform: Poster

Student Presentation: No

Does the growing-season weather impact spring wheat gluten strength in Western Canada?

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Wheat gluten strength is an important factor in bread baking. Variations in gluten strength present a challenge for both the milling and baking industries making it hard to keep consistent quality. Gluten strength varies with genotype, management practices and weather conditions. In Western Canada growing-season weather fluctuates. This study aims to identify climatic factors that impact spring wheat gluten strength and the period when the impact is significant in Western Canada. Nonparametric statistical methods were used since they are suited to deal with collinearity among predictor variables, which is usually the case with weather variables. Crop and weather data collected from wheat trials across Western Canada in 2015-2016 were used. Wheat characteristics linked to gluten strength including grain kernel properties, mixograph work input and protein fractions were analysed and used as dependent variables. Numerous parameters derived from the weather data were used as predictors. Preliminary results show that there is not one specific climatic variable related to all gluten strength parameters and not one specific growth stage when the relationship is significant. However, total GDD5 from planting-anthesis has a negative linear correlation ($p < 0.01$) with thousand kernel weight (TKW) and test weight (TW), but positive correlation with fusarium damaged kernels (FDK). Also, total ETC from anthesis-maturity has a positive correlation ($p < 0.05$) with TKW and TW, but a negative relationship with FDK. Dekadal total precipitation around anthesis has a negative correlation ($p < 0.05$) with GSI_p, the ratio of insoluble glutenin to flour protein (IG/FP), dough development time (DDT), work input to peak (WIP) and work input to peak2 (WIP2), but a positive correlation with grade and FDK. Interestingly, dekadal total ETC as well as average dekadal temperature just before/at anthesis are correlated to 11 of the 16 gluten strength parameters. Further analysis continues.

Preferred Platform: Poster Presentation

Student Presenter: N

CSSS_01: Biochar as an amendment in temperate soils

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**Soil Amendment with biochar for the enhancement of soil fertility and crop productivity -
Labrador's perspective**

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The soils of Happy Valley-Goose Bay (HV-GB), Newfoundland and Labrador, Canada have high acidity, sandy soil texture, low cation exchange capacity (CEC), poor soil structure, and low water and nutrient holding capacity. A number of multi-year experiments were conducted to evaluate (i) whether application of biochar (a carbonaceous substance produce from pyrolysis of biomass) could resolve the limitations mentioned above when applied singly or in combination with fishmeal and chemical fertilizers (ii) the macro and micro nutrient supplying capacity of biochar (iii) effects of biochar rates on crop productivity, soil health, and greenhouse gas emission. All experiments were set up on permanent layouts and the treatments were repeated in randomized block designs. Canola and beet were grown as test crops. Biochar application rates up to 80 t C/ha were able to increase soil pH, SOM (soil organic matter), CEC, soil moisture content (both gravimetric and volumetric), and the availability of Ca, K, S and Mn at the topsoil (0-15 cm). Biochar applied singly was unable to support crop establishment, growth and biomass production. Similarly, mineral fertilizer or fishmeal only treatments also were unable to produce satisfactory yields. However, combined application of biochar and fertilizer or fishmeal boosted crop establishment and growth and thus, produced significantly higher crop yields. The soil analysis and biomass yield data from the last five years of experimentation also suggest that onetime application of biochar may not be able to provide permanent beneficial effects on soil health and crop productivity.

Preferred Platform: Oral Presentation

Student Presenter: N

Effect of biochar on hydraulic properties and van Genuchten parameters of agricultural podzol

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Northern regions soils are generally classified as having lower agronomic value. Literature suggests that biochar (BC) amendments have positive effects on physiochemical properties resulting in improved soil health. One of the central benefits of BC is its influence on soil's hydraulic properties, such as soil water content (SWC) and water holding capacity (WHC). As these effects are highly related to the applied BC amount and soil type, field level information on the understanding of interactions between BC and podzol are relevant for the assessment of crop growth and yield. We investigated the effects of four different BC incorporation rates (10, 20, 40, 80 t ha⁻¹) and its maturation on hydraulic processes of converted podzol in Labrador, Canada. BC was incorporated within a one-year interval, allowing an assessment of its maturation. Continuously measured SWC and weather data during the growing season were analyzed. The SWC responses to rain events showed a clear distinction between storage parameters (i.e. initial, peak and final SWC) and kinetic parameters (i.e. amplitude and gain velocity). While storage parameters, wetting and drying progress were significantly affected ($P < 0.05$) by BC rates and maturity, the effects on kinetic parameters were minor. Effects were stronger for higher BC rates. WHC was also positively influenced by BC. Significant maturation effects on storage parameters were found for most BC rates, however not for kinetic parameters. Variability in van Genuchten parameters for different BC rates and individual rain responses revealed significant temporal variation on α ; while n was significantly affected by BC rates. Simulations showed similar infiltration rates for all BC rates, but slower drying rates with BC. Moreover, we found significant negative correlation between BC rates and saturated hydraulic conductivity. On our soil, a BC rate of 40 t ha⁻¹ provided the most favorable hydraulic property.

Preferred Platform: Oral Presentation

Student Presenter: N

**Increased retention of soil nitrogen over winter and early spring by biochar application:
implications for plant nitrogen availability**

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While soil nitrogen losses over winter and early spring can be substantial in northern temperate regions as a result of soil freeze-thaw, biochar as a soil amendment could mitigate these effects. However, there may be variation in the effectiveness of different biochar formulations with respect to their abilities to promote soil nutrient retention. We added N-15 tracer to soil mesocosms to examine the effects of biochar produced under a series of pyrolysis temperatures (250-600 degrees C) on soil nitrogen retention in response to variation in soil freeze-thaw cycle intensity (-10 degrees C vs. 0 degrees C following spring melt). We also examined the subsequent effects on plant nitrogen uptake, soil nitrous oxide emissions and nitrogen leaching losses. Increased soil freezing increased inorganic nitrogen leaching losses and decreased the subsequent biomass of the *Eruca sativa* test crop. Biochar amendment increased both soil N-15 retention over winter and the subsequent plant N-15 uptake, with the biochar generated at the highest temperature exhibiting the strongest effects on plant N-15 uptake. Biochar addition also significantly mitigated the negative soil freezing effect on subsequent plant biomass, but biochar addition combined with freezing increased soil nitrous oxide emissions. We also used a snow removal experiment to examine how biochar amendment interacts with increased soil frost over winter. Inorganic N losses, captured using resin bags installed at the bottom of each mesocosm, were reduced by 9% by biochar amendment. Biochar pyrolysis temperature, which was associated with increased soil pH, was negatively correlated with microbial biomass nitrogen. Biochar addition also had a positive effect (20%) on the yield of *Eruca sativa*. Overall, our results confirm that biochar application can mitigate soil nitrogen losses over winter, potentially benefitting plant yield.

Preferred Platform: Oral Presentation

Student Presenter: N

Climate change resilience of biochar amended soil and its impact on soil health in a temperate agricultural system

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Biochar is a charcoal produced by the pyrolysis of plant biomass. Biochar is used as an agricultural soil amendment in tropical agroecosystems, but its impact on temperate soil remains unclear. Therefore, the objective of this study is to investigate the resiliency of biochar amended soil to current ambient and future climate scenarios. A loam textured soil with different soil treatments [6 t/ha poultry manure plus 135 kg N-fertilizer/ha (MN)]; [3 t/ha poultry manure plus 3 t/ha biochar (MB); and 3 t/ha poultry manure, 3 t/ha biochar plus 135 kg N/ha (MNB)] was exposed to various climate settings: current ambient atmospheric CO₂ concentration and temperature (AMB), CO₂ fertilization (fCO₂), warming (TEMP), and the coupled effect of warming and CO₂ fertilization (TEMPxfCO₂) over 90 days. Soybeans (*Glycine max* L. Mer.) were grown in each soil treatment type and climate setting. Results showed a significantly higher (P<0.05) soybean shoot biomass under AMB conditions, and higher root plant height, and shoot biomass under TEMP conditions. MB soil amendment had the greatest NH₄⁺ and NO₃⁻ concentrations followed by MN and MNB under AMB and TEMP conditions. However, MB had the lowest PO₄³⁻ concentration followed by MN and MNB under both AMB and TEMP climate settings. The greatest quantities of NO₃⁻ and PO₄³⁻ were observed in TEMP in all soil treatment types. Soil organic carbon, total nitrogen, dissolved carbon, microbial biomass and microbial community structure are currently under evaluation for the first two climate settings (AMB and TEMP). fCO₂ and TEMPxfCO₂ treatments are currently under the 90-day incubation period.

Preferred Platform: Oral Presentation

Student Presenter: Y

Biochar Impacts on the Sorption of Organic Chemical Compounds in Soils

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Biochars are carbon-rich porous materials typically produced under limited oxygen from a variety of different feedstocks exposed to pyrolysis temperatures ranging from 250 to 1200°C. Depending on the feedstock type and pyrolysis temperature, biochars can have different physiochemical properties. We hypothesize that biochar application to soil increases the sorption of organic chemical compounds in soils. Sorption quantifies the availability of a chemical for moving to groundwater and surface water. The study design utilized twenty-six different biochars that were individually mixed at 4% rate (w/w) into a sandy clay loam soil rich in iron oxides (SCL-Fe₂O₃) and a clay loam soil rich in calcium carbonates (CL-CaCO₃). A series of batch equilibrium experiments were conducted to calculate the amount sorbed (%) of sulfamethazine (antimicrobial), 17β-estradiol (natural steroid estrogen), and 2,4-dichlorophenoxyacetic acid (2,4-D), glyphosate and atrazine (all herbicides) in soils and biochar amended soils. Results indicated that the response to biochar additions on chemical sorption was very different for glyphosate than for the other four chemicals. Most biochar additions did not significantly impact glyphosate sorption: in fact, five and seven biochars significantly decreased glyphosate sorption in SCL-Fe₂O₃ and CL-CaCO₃ soils, respectively. For the other four chemicals, biochar additions significantly increased sorption or had no impact, except that two biochars significantly decreased 2,4-D sorption in both soils. In the SCL-Fe₂O₃ soil, chemical sorption significantly increased in case of 17 biochars for sulfamethazine and 2,4-D, 16 biochars for 17β-estradiol, and 14 biochars for atrazine. In the CL-CaCO₃ soil, chemical sorption significantly increased in case of 23 biochars for 17β-estradiol, 22 biochars for sulfamethazine, 21 biochars for atrazine, and 16 for 2,4-D. Of these significant increases, four biochars enhanced the sorption of sulfamethazine, 17β-estradiol, atrazine and 2,4-D in both soils to 100%, thus making the chemicals immobile for movement by water in soils. Applying the Scanning Electron Microscope (SEM) technique, biochars were shown to have different porosity characteristics. Synchrotron based X-ray Absorption Near-Edge Structure (XANES) spectroscopy was applied to explore which carbon functional groups in soils and biochars are associated with enhanced organic chemical sorption.

Preferred Platform: Oral Presentation

Student Presenter: Y

Biochar use for sustainable horticulture: Effect on sweet pepper yield and on growing medium properties

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Biochar properties are influenced by the feedstock used and pyrolysis temperature. The effects of three biochars made from maple bark at 550°C (M550) and 700°C (M700), and from pine chips at 700°C (P700), incorporated at three rates (5, 10 and 15% by volume) in a growing medium (GM), were tested on the productivity of sweet pepper (*Capsicum annuum*) under 50 and 100% of the recommended fertilizer. A greenhouse experiment was conducted for 63 days using a randomized complete block design to compare the control-GM with the nine biochar-GMs treatments. Plant yield and physicochemical and biological properties of GMs were measured. In general, under both fertilization levels, addition of biochars at all rates increased ($p < 0.05$) the pepper shoot dry matter yield compared to the control. Fruit yield increased by 39–55% in M550 (10%), M700 (5, 10 and 15%) and P700 (5 and 10%) compared to the control. Maple biochars reduced NO_3^- and PO_4^{3-} in leachates, while they increased pH and dissolved organic carbon (DOC) as compared to the control. The addition of 15% M700 biochar had the highest positive impact on bacterial richness in GM. In comparison to GM without biochar, values of Faith's PD index increased by 15% in M700 and by 9% in M550 and P700. Chao1 and Shannon indices were respectively 15% and 6% higher in M700 and P700 compared to the control and M550. Shift in bacterial composition effect was strongly correlated with DOC content from M700. Beneficial bacteria associated to plant growth such as genera *Devosia*, *Streptomyces*, and *Cellvibrio* increased in abundance in response to biochar amendments. Results suggest that the positive effects of biochar on plant yield can be attributed in part, to the increase in bacterial richness and shifts in bacterial composition towards beneficial heterotrophic bacteria. From a sustainable viewpoint, addition 15% M700 biochar reduced the nutrient losses by leaching and reduced fertilizer inputs by 50% without affecting pepper yield.

Preferred Platform: Oral Presentation

Student Presenter: Yes

Soil health and greenhouse gas emissions: a study of biochar as an amendment in temperate agriculture

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While biochar as a soil amendment is not a novel concept, the addition of biochar into temperate agricultural soils represents relatively new territory. Few long-term field studies have quantified temporal effects biochar imposes on GHG emissions or soil health of temperate agricultural soil. The objectives of this study were to quantify differences in soil characteristics among treatments, to determine temporal variations in GHG emissions, and determine the relationship between emissions and soil characteristics in temperate agricultural soils following biochar additions [3 t/ha poultry manure plus 3 t/ha biochar (MB); 3 t/ha poultry manure, 3 t/ha biochar plus 135 kg N/ha (MNB)] compared to a no-biochar control [6 t/ha poultry manure plus 135 kg N/ha (MN)]. Results showed that the majority of analyzed attributes were unchanged by biochar additions. Soil moisture, temperature, and PO₄₃- were however significantly greater ($p < 0.05$) in the MN treatment while C/N ratio and bulk density was significantly lower ($p < 0.05$). Though not significant treatments with biochar (MB, MNB), had a positive impact on corn (*Zea mays* L.) grain yield and aboveground biomass productivity during the first season biochar was added to the soil. This, however, was not observed for the soybean (*Glycine max* L. Mer.) crop in the second year after biochar addition. Soil CO₂ and N₂O emissions were not significantly different ($p < 0.05$) among treatments in 2016 and 2017, although a general trend showed that biochar amended soil emitted $\sim 5\text{--}10 \text{ mg CO}_2\text{-C m}^{-2} \text{ h}^{-1}$ less CO₂ than the MN treatment, but $\sim 10\text{--}15 \text{ g N}_2\text{O -N m}^{-2} \text{ h}^{-1}$. Results from this study revealed that in general, the low level of biochar added had few impacts on soil health and greenhouse gas emissions while still offering a mechanism for storing carbon.

Preferred Platform: Oral Presentation

Student Presenter: Y

High-performance growing media for vertical agriculture in Northern environment

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High-performance growing media are needed to develop vertical farming for Northern and remote communities. The aim of this study was to evaluate the agronomic performance of three edible plants (lettuce, endive and Chinese cabbage) grown on 10 growing media (combination of conventional materials; coir and peat) combined or not with three soil amendments (biochar, worm-casting and biostimulants). A pot experiment using a randomized complete block design with four replicates was conducted in a greenhouse located at Agassiz Research and Development Centre (Canada) in collaboration with ARO, The Volcani Center (Israel). Parameters measured were the growing media physico-chemical properties as well as their biological properties and plant performance (e.g. fresh and dry plant biomass, yield, nutrient content, SPAD, Fm/Fv). Results will be discussed in terms of the most promising growing media adapted to vertical farming and practices for sustainable management of water and fertilizers. The outcomes of this study regarding the (1) fulfilment of consumers' demands for local and healthy food especially for remote community, (2) the contribution to the economic development and resource conservation in Canada and Israel, and (3) the reduction of greenhouse gas emissions and fertilizer leaching into the environment, helping to minimize the environmental footprint of food production and mitigate impacts of climate change, will be discussed.

Preferred Platform: Oral Presentation

Student Presenter: NO

Characterization of Biochar Carbon Functional Groups as determined by XANES, NMR and ATR-FTIR spectroscopy

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Biochar is considered an efficient tool to increase soil fertility and carbon sequestration. It has been proposed that biochars can be applied to soils or in bio-beds for mitigating chemical off-site transport, while biochars may also aid chemical removal in water and wastewater treatment. Characterization of biochar carbon functional groups is important for understanding the reaction of chemicals with biochars, and hence biochar practical applications. The objective of this study was to characterize organic carbon functional groups of more than 20 different biochars produced from different feedstocks and pyrolysis temperature ranges from 350-1500 °C. Three techniques were used and compared for the information they generated: Synchrotron based X-ray Absorption Near-Edge Structure (XANES) spectroscopy, solid-state ¹³C Nuclear Magnetic Resonance (NMR) spectroscopy and Attenuated Total Reflection-Fourier Transform Infrared (ATR-FTIR) spectroscopy. XANES and ATR-FTIR techniques were successful in characterizing the functional groups for all the biochars. However, NMR was not successful for a wide range of biochars possibly because of the interference of the magnetic particles in the biochars. ATR-FTIR was less useful than XANES and NMR in providing for quantitative data. Both XANES and NMR demonstrated that aromatic carbon is often dominant when quantifying the relative proportions of organic carbon functional groups in biochars. XANES carbon spectra showed that aromatic carbon and carboxylic groups are significantly negatively correlated ($r = -0.99$, $p < 0.0001$).

Preferred Platform: Oral Presentation

Student Presenter: N

Effects of biochar on fresh organic matter decomposition, microbial activity and C use efficiency

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Biochar is a carbon rich product derived from pyrolysis of organic material which improves soil biogeochemical properties and crop production. We investigated the effects of corncob-derived biochar on native and fresh organic matter (corncob residue) decomposition in nutrient poor Aridisols. The surface soil (0-15 cm layer; <0.1% organic matter) used in the experiment was collected from an agricultural field under wheat cultivation. The treatments included: 1) unamended control, 2) residue (2%, w/w), 3) biochar (2%, w/w), and 4) residue + biochar (1% each, w/w). Rate of biochar and corncob residue application either alone or combined was equivalent to 45 tons ha⁻¹. Each treatment was replicated four times and experiment was laid out following completely randomized design (CRD) at 70% water holding capacity and 25 °C for 54 days. Soil C mineralization was quantified by measuring soil respiration. At the end of the experiment, soil samples were analyzed for soil C and N mineralization indicators, and physico-chemical properties. Biochar reduced decomposition of fresh organic matter and induced negative priming effect. Decrease in C mineralization in biochar amended soil could be due to the strong adsorption of soluble soil C, nutrients and microbes on the surface of biochar resulting in enhanced C use efficiency and reduction in activity of C mineralization enzymes. This was also evident from the reduced values of microbial metabolic quotient (qCO_2). Another mechanism for the reduced rate of C mineralization could be CO_2 adsorption on biochar surface as carbonate. The decrease in mineral N after biochar incorporation could indicate that organic N was assimilated into microbial biomass rather than being mineralized. In conclusion, biochar could decrease C mineralization but enhanced microbial C use efficiency. Higher N retention in biochar-amended soil could lead to reduced rates of N_2O emissions and N leaching due to N immobilization and fixation by microorganisms.

Preferred Platform: Oral Presentation

Student Presenter: N

A summary of observations of the interaction between biochar, plant productivity, mycorrhizal fungi and soil types in Western Australia.

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Over the period 2000- 2017 18 field experiments in the W.A. wheat belt, 20 field experiments on the W. A. swan coastal plain and 12 pot trials were undertaken to evaluate the effect of biochar soil amendments on plant growth. A meta – analysis of wheat responses showed, in experiments where there was a positive response, the mean increase in grain yield was between 18.6 and 65.6% ($p = .05$) at biochar application rates between 2.5 – 7.5 tons per ha. The largest wheat yield responses were observed in pelleted mycorrhizal biochar applied in bands below crop rows. Yield responses were observed 6 years after incorporation of biochar. Multiple regression analysis of non-responsive and responsive trials indicated that grain yield response was correlated with soil chemical properties. Statistically significant yield responses, in field trials of 10 commercial horticultural crops planted on the swan coastal, to biochar applied as mycorrhizal inoculated pellets varied from 15 -25% at biochar application rates of 10 tons per ha. Field and greenhouse experiments indicated that the response to biochar was: significantly greater when biochar was concentrated in bands, inoculated with mycorrhizal spores and when fertiliser rates were reduced by 50% from recommended practice. In field and pot trials it was demonstrated that the vertical fine root distribution and concentration was markedly increased by biochar incorporation. Field observations and root box experiments suggest that plant roots are attracted to biochar concentrated in pellets by factors other than soil moisture or nutrients. An alternative hypothesis is proposed to explain the response to crops to biochar.

Preferred Platform: Oral Presentation

Student Presenter: No

An economic evaluation of the integration of pyrolysis of farm residues to produce biochar and energy into broad scale wheat cropping in Western Australia

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Two excel models were developed to determine the effect of varying the inputs from base case levels, derived from field studies, of the major factors effecting biochar costs and farmer return from biochar incorporation and energy utilization. The calculations are based on a 20 year investment period. The proportions of biochar total costs of feedstock, operating costs, capital (interest per year) and transport costs were 63%, 23%, 11% and 4% respectively. The cost of biochar at base level inputs is \$287. If the returns from utilization on farm of 50% of the gas produced from pyrolysis are discounted the cost is reduced to \$230 t⁻¹. A sensitivity analysis showed that feedstock cost was the most important factor effecting biochar cost. A reduction of feedstock cost by 40% reduces biochar costs to \$156. The farmer return; assuming yield increases of 18%, biochar application rates of 4 t⁻¹, biochar costs including transport and application costs of \$876 ha⁻¹, a 50% reduction in fertilizer fertilizer costs and a carbon price of \$20 t CO₂e⁻¹; is 3%, 10% and 15 % at longevity of growth responses of 7,10 and 20 years respectively. A sensitivity analysis showed that biochar application rate, biochar cost, yield response and carbon price were the major factors effecting farmer return. It is unlikely, for practical reasons, that significant increases in farmer return could be achieved by advantageous changes in all output and input variables except carbon price and feedstock costs. If the carbon price was increased to \$40 t CO₂e⁻¹ the return, for a longevity response time of 10 years, would be increased from 10% to 15%. Reduction of feedstock costs by 40% would increase the farmer return from a 10-year duration growth response from 10% to 15%. It is feasible that reductions in the cost of feedstock of this magnitude could be achieved by utilization of the feedstock from tree crops, integrated into farms, which are harvested for the production of eucalyptus oil.

Preferred Platform: Oral Presentation

Student Presenter: N

Effect of Biochar on TDR based Volumetric Soil Moisture Measurements in a Loamy Sand Soil

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Time Domain Reflectometry (TDR) is a well-established method for measuring volumetric soil moisture content (VSMC) at point scales using soil's dielectric properties. The method assumes that soil properties are uniformly distributed and has negligible influence from other physical properties; hence this method can be used in a wide range of soils. With the increasing interest in biochar (BC) as a soil amendment in agriculture, management practices also need to be adjusted for changing soil properties. Here we evaluated the effect of BC incorporation on TDR based soil moisture measurements. The tested soil was a loamy sand (73.7 ± 4.1 % sand, 23.0 ± 3.8 % silt, 3.3 ± 0.3 % clay). BC of two distinct particle sizes, i.e. powdered (0.5 mm) and granular (1-6 mm) were used. Ten different soil: BC mixtures, including non-BC (0%) and BC-only (100%), were packed to a 1.25 g/cm^3 bulk density in plastic containers (volume 750 mL). To calculate VSMC from dielectric constant obtained from a TDR cable tester (MOHR CT 100), Topp's equation–M1 (Topp et al. 1980), mixing model–M2 (Roth et al. 1990) and the forest soil model–M3 (Schaap et al. 1996) were used. The three models were compared with a standard (M0) VSMC calculated using gravimetric moisture and soil bulk density. According to the results from regression analysis; the M1 and M2 reported significantly lower values, while M3 reported higher values than M0 for both powdered and granular BC treatments ($p=0.000$). However, for powdered BC treatment, the relationships between M1, M3 with M0 were not significant ($p=0.228, 0.052$) while it was significant for M2 with M0 ($p=0.028$). For granular BC treatments, the M2, M3 with M0 regressions have shown significant similarity ($p=0.009$ & 0.032); this was not true for the M1 to M0 comparison ($p=0.571$). These results show that the effects of types and rates of BC on VSMC prediction models based on soil dielectric constant need to be further studied under both laboratory and field conditions.

Preferred Platform: Oral Presentation

Student Presenter: Y

Nematode and micro-arthropod diversities as indicators of soil fertility in biochar amended agriculture soil in Labrador, Canada

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Newfoundland and Labrador, Canada (NL) has a boreal climate with characteristic podzolic soil. Climatically ruled limitations, such as excessively acid soil conditions, a short growing season, and harsh winters, make NL uniquely challenging for agriculture development. Biochar application is being considered as a way to amend and improve the quality of soils newly converted from boreal forest to agricultural use. We hypothesised that biotic indicators of soil health, including a change in nematode and micro-arthropod communities, would reflect the positive impact of biochar addition. An agricultural field located in Happy Valley-Goose Bay, Labrador was surveyed. Soil received 8 treatments, 10, 20, 40, or 80 t C Ha⁻¹ biochar added in 2016 (new), and 10, 20, or 40 t C Ha⁻¹ biochar added in 2013 (old). The control received no biochar. Extractable free-living nematode and soil micro-arthropod counts and functional classifications were assessed. Nematodes were extracted using the decanting and sieving method followed by the use of extraction pans. Samples were further cleaned after preservation using the centrifuge flotation method with MgSO₄ 1.28. Micro-arthropods were extracted using the Tullgren/Berlese funnel technique. All biochar amended soil showed a trend towards greater nematode abundance than control soil. Only two micro-arthropod orders were found; Collembola and Coleoptera. Collembola was found in new and old plots with 20 t C Ha⁻¹, Coleoptera was found in the new plot with 80 t C Ha⁻¹. No arthropods were found in the control soil. Biotic indicators, including soil pH, CEC, organic matter, and extractable cations were also analysed, and employed as contextual covariates in the analyses.

Preferred Platform: Oral Presentation

Student Presenter: Y

Assessment of Physicochemical Properties of a Loamy Sand Soil Treated with Dairy Manure and Biochar in Western Newfoundland

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Physicochemical properties of soils determine the fate of plant growth and development through various processes within the root zone. Such processes are altered largely due to human interventions through agricultural practices. Dairy manure (DM) and biochar (BC) applications are considered to improve soil health and plant growth. Therefore, a field study was conducted at Pynn's Brook Research Station in western Newfoundland to evaluate the effects of DM and BC on various soil properties, as well as to establish a relationship between soil electrical conductivity (EC) and selected properties. Experimental treatments comprised of four replicates of control, inorganic nitrogen (IN), IN+BC, DM, and DM+BC. Dairy manure (30,000 L/ha) and BC (20 t/ha) was applied and mixed within the top 20 cm of the loamy sand soil [73.7(±4.1) % sand + 23.0(±4.1) % silt + 3.3(±0.3) % clay]. Disturbed soil samples were collected at 0-10 and 10-20 cm depth from each plot on 65, 72, 129 and 139 days after soil amendments (DASA). Results showed non-significant ($p > 0.05$) effects of treatments on gravimetric and volumetric moisture contents, soil pH, ammonium nitrogen ($\text{NH}_4^+\text{-N}$), cation exchange capacity (CEC), or EC within each field day. Whereas, significant temporal variations were recorded for pH, $\text{NH}_4^+\text{-N}$, and EC – both apparent electrical conductivity (ECa) and soil solution EC (ECw). The decrease in $\text{NH}_4^+\text{-N}$ could possibly be attributed to volatilization, plant uptake, immobilization by microbes, or conversion to nitrate-N, while EC decrease may be due to a corresponding decrease in ionic concentration by plant uptake and leaching. No significant differences were observed between both soil depths within each treatment for the tested properties. Positive correlations were recorded for EC with SOC, $\text{NH}_4^+\text{-N}$, and CEC (ECa, ECw 0-10 cm & ECw 10-20 cm, $p=0.000$). Once correlation data has been validated, ECa could be used to map the variability of respective soil properties for similar soils in NL.

Preferred Platform: Poster Presentation

Student Presenter: N

Mechanistic evaluation of biochar effects on the diversity and activity of microorganisms during composting

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In recent years, biochar was proposed as additive and bulking material for composting facilities. Due to its large surface area, high porosity, surface functionality and chemical recalcitrance, biochar may improve the biological, chemical, and physical properties of the decomposing organic waste and the compost produced from this process. However, little is known about the mechanisms whereby biochar regulates the diversity and activity of microorganisms during composting. The objective of this work was to review the literature describing biochar effects on the composting process and compost quality, with emphasis on the dynamics of microbial populations in biochar-compost mixtures. Analysis of the literature on this topic revealed that biochar regulates the diversity and activity of microbial populations by four possible mechanisms: (1) biochar provides habitat for bacteria and fungi in its micropores as well as on its surface, (2) biochar adsorbs dissolved substrates (e.g., nutrients) released from decomposing organic materials, making them available to the microorganisms associated with biochar particles, (3) biochar creates favorable microenvironments, by modifying the density, pH and moisture content of the composting mixture, and (4) biochar adsorbs inorganic and organic pollutants, particularly trace metals in a composting mixture, which reduces microbial exposure to potentially toxic compounds. Soil receiving a biochar-compost mixture has unique soil microbial dynamics and plant productivity, compared to soil receiving biochar alone or compost alone. This work provides new mechanistic insights into biochar-mediated changes during composting. The advantages and disadvantages of incorporating biochar into the composting process, related to compost quality and soil health, will be discussed.

Preferred Platform: Poster Presentation

Student Presenter: Y

Biochar amendments: Beneficial effects for plant productivity and for environment

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Biochar is a promising avenue for sustainable agriculture, but its beneficial utilization in horticulture is not well known. Since biochar properties are influenced by feedstock and pyrolysis temperature, three biochars made from maple bark at 550°C (M550) and 700°C (M700), and from pine chips at 700°C (P700) were incorporated at three rates (5, 10 and 15% by volume) in a growing medium (GM). Two greenhouse experiments were conducted for 63 days using a randomized complete block design to compare the control with the nine biochar treatments. The effects of biochar on yield of tomato (*Solanum lycopersicum*) and sweet pepper (*Capsicum annuum*), under 50% and 100% of the recommended fertilizer, and its ability to improve water use efficiency (WUE) were evaluated. Properties of GMs were also measured. Biochar amendments usually improved the yields of tomato and pepper. Dry biomass of plants, under low fertilization, was higher ($p < 0.05$) in biochar treatments than in control, particularly with pepper. Use of 10% M550 and 5% M700 with complete fertilization increased shoot and root biomass of pepper compared to the control. Biochars altered the GM properties in different ways according to the application rates of biochar, plant species and fertilization level. In both experiments, M550 and M700 increased soil pH compared to the control. These biochars also increased the dissolved organic carbon (DOC) and soil respiration, especially in the pepper crop. P700 had a lower impact on soil nutrients. In the presence of biochars, WUE was higher under low compared to the complete fertilization. Results suggest that high pH, water retention, and DOC content are biochar properties favoring microbial activity and water use efficiency, thereby contributing to improvement of plant growth. Our work indicates that biochar amendment can promote productivity of tomato and pepper, while reducing the use of fertilizers and water, thus contributing to substantial environmental benefits.

Preferred Platform: Poster Presentation

Student Presenter: Y

Effects of biochar on maize (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.) biomass in a temperate field study

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Biochar, or land-applied pyrolyzed biomass, has been found to increase crop productivity and sequester carbon (C) in tropical regions. However, there is limited research in temperate climates under field conditions. Therefore the objective of this study was to examine the effects of a moderate amount of biochar on maize (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.) grown under conventional agricultural practices over two growing seasons in southern Ontario, Canada. The replicated treatments included a control with 6 t/ha poultry manure and 135 kg/ha nitrogen (N) fertilizer (MN); 3 t/ha poultry manure and 3 t/ha biochar (MB); and 3 t/ha poultry manure, 135 kg/ha N fertilizer and 3 t/ha biochar (MNB). The results showed that biochar had no significant ($P > 0.05$) negative impact on root biomass or shoot-to-root ratio. There was a trend of increased root biomass, as the MNB treatment increased root biomass by 14.5 and 9.8% in maize and soybean respectively, thus indicating increased belowground C inputs. However, the same treatment decreased crop yield by 13.4 and 17.4% for maize and soybean respectively. Generally, more positive results were seen in the first year, which was a drier than average year. The loamy soil type, temperate climate, and relatively low application rate, and other unknown factors all could have contributed to the insignificant biomass change. This research indicates that C sequestration and other benefits of biochar could be exploited without significant negative impacts on biomass under these field conditions. Additionally, it highlights the need for future studies with more sensitive plants, poorer soils, drier climatic conditions, and higher application of biochar.

Preferred Platform: Poster Presentation

Student Presenter: Y

Effect of biochar on small fruit yields and quality in Quebec, Canada

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The market for small fruits (grapes, strawberries, blueberries and raspberries) is valued at over C\$100,000,000 per year in Quebec. Farmers seek to produce small fruits with high yield and quality. Biochar could be used as a soil amendment to improve soil quality, which may promote small fruit growth. The objective of this research was to determine if biochar affects yield and quality of the small fruits. The experimental sites were located on farms in southern Quebec and the experimental design for each type of small fruit was completely randomized with five replicates. Data on small fruit yield and quality indices are analyzed by SAS 9.8 with one-way analysis of variance (ANOVA) and multiple principal components analysis. An optimized model will be constructed to evaluate small fruit yields and quality. The effect of biochar on small fruit yields and quality under Quebec growing conditions will be discussed.

Preferred Platform: Poster Presentation

Student Presenter: Y

CSSS_02: The scope of soil carbon; measuring, understanding and increasing soil carbon storage within horizons and across biomes

Co-Conveners: Scott Chang¹, Hida Manns²

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Forested land-use increases soil carbon storage in agroforestry systems in western Canada

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Trees planted on the agricultural landscape are widely regarded as beneficial for reducing wind speed, minimizing erosion risks, and diversifying farm operations; however, the effect of trees (in the forested land-use) on soil carbon storage in agroforestry systems is not well understood. A large scale project was initiated in Alberta to investigate the effect of trees or the perennial vegetation on soil carbon storage, and carbon distribution in particle size/density fractions in three agroforestry systems, shelterbelt, hedgerow and silvopasture, across 36 sites. Within each agroforestry system, the forested land-use consistently had greater total organic carbon in the bulk soil, in particle size fractions and in density fractions than the agricultural land-use. When soil samples were collected to the 75 cm depth, the forested area had greater soil organic carbon (SOC) in the 0-75 cm mineral soil (25.5 kg C m^{-2}) than the herbland (including cropland and rangeland) (19.4 kg C m^{-2}), driven by the greater SOC level in the top 0–30 cm rather than in the deeper layers (30–75 cm). In the forested area the SOC content in the 0-10 cm layer was positively related to the C content of the overlying LFH (litter, partially decomposed litter and humus) layer. Our data suggest that agroforestry systems are effective in increasing carbon storage in central Alberta. Including trees in the agricultural landscape should be encouraged to realize the benefit of practicing agroforestry in Canadian agriculture.

Preferred Platform: Oral Presentation

Student Presenter: N

Separation of soil respiration; comparison of partition methods

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Without accurate data on soil heterotrophic respiration (Rh), assessments of soil carbon (C) sequestration rate and C balance are challenging to produce. Accordingly, it is essential to determine the contribution of the different sources of the total soil CO₂ efflux (Rs) in different ecosystems, but to date, there are still many uncertainties and unknown regarding the soil respiration partitioning procedures currently available. This study compared the suitability and accuracy of five different Rh/Rs partitioning methods in a subtropical forest: (1) regression between root mass and root derived CO₂; (2) root exclusion bags with intact soil blocks; (3) root exclusion bags with hand-sorted roots; (4) lab incubations with minimally disturbed soil microcosm cores; and (5) soil $\delta^{13}\text{C}$ -CO₂ natural abundance. The relationship between Rh and soil moisture and temperature was also investigated. A qualitative evaluation table of the partition methods with five performance parameters was produced. The Rs was measured weekly from February 3rd to April 19th 2017 and found to average $6.1 \pm 0.3 \text{ Mg C ha}^{-1} \text{ y}^{-1}$. During this period, the Rh measured with the in-situ mesh bags with intact soil blocks and hand-sorted roots were estimated to contribute $49 \pm 7\%$ and $79 \pm 3\%$ of Rs respectively. The Rh percentage estimated with the root mass regression, microcosm incubation and $\delta^{13}\text{C}$ -CO₂ natural abundance were $54 \pm 41\%$, $8-17\%$ and $61 \pm 39\%$ respectively. Overall, no systematically superior or inferior Rh/Rs partition method was found. The paper discusses the strengths and weaknesses of each technique with the conclusion that combining two or more methods optimizes Rh assessment reliability.

Preferred Platform: Oral Presentation

Student Presenter: N

Following carbon flows – from CO₂ to CO₂

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Renewed attention to soil health and the urgency of regulating climate has prompted widespread interest in enhancing soil carbon stores. Exploring and abetting the processes whereby carbon is stabilized in soil has therefore become a dominant theme in Soil Science. These soil-centric studies have been richly illuminating, but may sometimes evade a fundamental constraint: that replenishing soil carbon ultimately depends on photosynthesis. It is plants – not soils – that capture carbon from the air; it is plants that invest solar energy into this carbon which then streams through lands, driving all of their functions: producing food, promoting biodiversity, regulating climate, among others. In this reflective review, I contemplate how this familiar but bypassed knowledge might invigorate our studies of carbon sequestration. Beyond merely maximizing ‘stabilization’ of carbon, maybe we should aim instead for a malleable reservoir of soil organic matter that holds energy and nutrients in dynamic reserve, responsive to the fluctuating demands of ecosystem functions. Our target, then, might be farmlands that mimic the resilience of natural systems wherein soil organic matter rises and falls in synchrony with biotic demands upon it, securing maximum photosynthesis to sustain the many functions of land fueled by solar energy. One way of extending our perspective – following carbon through its full cycle from CO₂ to CO₂ – would be to forge stronger ties with other disciplines, perhaps especially in studying the rhizosphere: the roiling interface between plants, soil, microbes, and air.

Preferred Platform: Oral Presentation

Student Presenter: N

Macroaggregate formation and residence time as a regulator of soil organic carbon accrual: a systematic quantitative review

Alison E King, Katelyn A Congreves, Bill Deen, Kari E Dunfield, Paul Voroney, Claudia Wagner-Riddle

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Although interactions between edaphic and climatic factors are putative controls on soil organic carbon (SOC) concentrations, no factors that consistently explain SOC have yet been found. Given the importance of physical protection for SOC accrual, we hypothesized that SOC responds to macroaggregate formation and residence time. We conducted the first systematic review of studies reporting macroaggregate-occluded fractions, compiling 255 observations from 35 studies. Environmental variables (clay, MAT, MAP) explained at most 19% the variability in macroaggregate mass or SOC. In contrast, SOC concentrations were consistently and positively related to soil mass as macroaggregate. For each additional 1% soil mass in macroaggregates, soils increased SOC by 0.24 g kg soil⁻¹ (n = 224; 95% CI 0.16, 0.32). Among all variables, macroaggregate C kg soil⁻¹ had the strongest relationship with total SOC kg soil⁻¹ (R² marginal = 0.87). For each additional g SOC kg soil⁻¹, soils gained C preferentially in macroaggregates (1.07 g C kg soil⁻¹; n = 227; 95% CI 0.98, 1.19), as free microaggregate and free silt and clay C gained much less on a whole-soil basis. Occlusion in macroaggregates increased C concentration of the microaggregate size class and of silt and clay, which had 30% (SE = 3.7) and 37% (SE = 3.3) respective increases in C kg aggregate⁻¹ relative to their free counterparts. We suggest that macroaggregation enables silt and clay to approach C saturation and may delay decomposition of the SOC contained in microaggregates. We can infer that soils in the highest quartile of SOC had macroaggregate residence times or formation rates 51% higher than soils in the lowest SOC quartile, or moderately increased both residence time and formation rates. Our results show that macroaggregation is central to SOC accumulation and point to the need to better understand controls on the turnover of macroaggregates to both facilitate SOC accrual and predict SOC response to global change.

Preferred Platform: Oral Presentation

Student Presenter: Y

The soil carbon, water, texture equilibrium triangle as a universal measure of soil organic carbon change

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Modelling of soil carbon change in agricultural soils could be improved with a readily usable metric. The data collected over 50 cropland fields of the Canadian Prairie during the Soil Moisture Active Passive field sampling in early summer 2012 (SMAPVEX12), demonstrated high correlation among soil texture, organic carbon (SOC) and mean soil water content (SWC). The three measured variables (sand content, SOC and SWC) were calibrated to form a triangle following their linear regression relationships. We hypothesize that when soils are in equilibrium, the soil texture could be used to assess the capacity of soils to maintain SOC and soil water. The triangle model was tested with data from Elora, Canada, collected in 1999. SWC predicted from Elora sand content accurately measured SWC of Elora soils, while the prediction of SWC from Elora SOC was lower than measured SWC. The SOC prediction from sand content in Elora soils was lower than the triangle values, suggesting there was room for SOC to increase at sand values above 25%. The triangle would allow carbon anomalies to be comparable globally.

Preferred Platform: Oral Presentation

Student Presenter: N

CSSS_02

Evaluating soil carbon across biomes

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Soil carbon is a universal parameter in modelling atmospheric CO₂ change. Soil carbon content varies among agriculture, woodlands, peat bogs and tundra suggesting that soil carbon characteristics are not uniform across biomes when it comes to evaluation. For instance, carbon in temperate agricultural soil is bound over long time intervals into soil aggregates within organo-mineral complexes believed to be essential in the resistance of soil organic carbon to decomposition. In contrast, peat moss has a much higher organic carbon content (5x), but the physical composition and decomposition process differ substantially in the absence of formation of organo-mineral complexes. Forest soil carbon is physically similar to agriculture soils, but differs in formation, physical characteristics and sampling methods. This talk will discuss the state of knowledge of soil carbon measurement in the biomes common in Canada and issues in comparing soil carbon stocks across biomes.

Preferred Platform: Oral Presentation

Student Presenter: N

Macroaggregate persistence as an indicator of soil carbon storage resulting from crop residue

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Soil carbon (C) storage is related to soil structure. Within macroaggregates, soil organic C is retained through the physical occlusion of fresh and partially-decomposed organic residues from plants and animals. The mean residence time of macroaggregate-associated soil C may range from weeks to years, depending on the persistence of the macroaggregate. It remains difficult to quantify macroaggregate persistence, defined as the continued and unaltered presence of macroaggregates in the soil matrix during a given period of time, because multiple abiotic and biotic factors influence aggregate formation and destruction processes under field conditions. The objective of our study was to measure the macroaggregate persistence as influenced by crop residue inputs, and to assess the soil C content of persistent macroaggregates under field conditions. The experiment was carried on a working farm in Rivière Héva in northwestern Québec (48.2° N, 78.2° W). Soil mesocosms (polyvinyl chloride tubes, 10 cm diameter, 13 cm tall) were packed with clayey soil, and received approximately 0, 0.3, 0.5, 0.9, 1.2 and 1.5 t ha⁻¹ of wheat straw, which was placed at the soil surface or mixed in the top 6 cm. A digital camera was used to acquire images of soil surface macroaggregates during a 2-month period (July and August 2017). After image acquisition, surface macroaggregates were taken from each mesocosm for organic C analysis. Image alignment, resolution calibration and the removal of straws and plants from images were performed with Photoshop and ImageJ. A MATLAB program was written to detect macroaggregates that persisted in time. The relationship between persistent macroaggregates at the soil surface and the soil C associated with these macroaggregates will be described.

Preferred Platform: Oral Presentation

Student Presenter: Y

Long-term forest soil warming and nitrogen addition changes soil organic matter composition

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Soil organic matter (SOM) is the largest pool of actively cycling organic matter and two-thirds of this SOM is stored in forest soils. As global temperatures and atmospheric concentrations of greenhouse gases continue to rise, it is important to maximize the carbon (C) storage capacity of SOM. At the same time, it is unclear how forests will respond to future environmental conditions, including warmer temperatures and greater rates of nitrogen (N) deposition. To better understand the relationships between long-term warming, N addition and SOM composition, a study site was established at Harvard Forest, MA in 2007. At this site four treatments were applied continuously: Control, Warming (soil temperature was increased by 5 °C using heating cables), N-Addition (N applied annually as NH_4NO_3) and Warming+N (a combination of the Warming and N-Addition treatments). After ten years, the O and A horizons were sampled and analysed at the molecular level using biomarker methods and nuclear magnetic resonance (NMR) spectroscopy to measure SOM composition and degradation state. Results of NMR spectroscopy show that in all treatments, the SOM in the A horizon is more degraded than in the O horizon, which is receiving continuous fresh inputs from above-ground litter. The Warming treatments appear to have accelerated degradation, particularly in the A horizon. In contrast, the N-Addition may have suppressed degradation. The response of the Warming+N treatment is most similar to the Warming treatment, which suggests that after ten years, soil warming controls degradation more strongly than N-Addition. These results will be presented along with supporting evidence from biomarker compounds, including lipids, suberin, cutin and lignin. Molecular-level data will provide detailed information about SOM composition and biogeochemistry, which will improve understanding of the relationship between future climate change and C storage and cycling in temperate forests.

Preferred Platform: Oral Presentation

Student Presenter: Y

Building soil organic matter in potato-based systems with high residue cover crops

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Potato crop returns a low amount of residues and is associated with intensive and frequent soil tillage which accelerates soil organic matter mineralization. Strategies that can help to sustain soil organic matter include manure incorporation and/or growing high residue cover crops. The objective of this study initiated in spring 2017 was to test the ability of different summer cover crops with and without pen pack cow manure in increasing soil organic matter under a 3yr (cover crop-potato-barley) potato rotation system. Manure was applied at 20 Mg ha⁻¹ (wet weight basis). Eight different summer cover crops replicated four times were grown: 1) alfalfa/orchardgrass mixture; 2) sorghum sudan grass; 3) red clover; 4) ryegrass/common vetch/crimson clover; 5) forage pearl millet; 6) sorghum sudan grass/ verticillium resistant alfalfa; 7) winter rye/hairy vetch; and 8) forage sorghum sudan grass. Manure effect was not significant on total above ground dry matter and on total N accumulation but cover crop effect was significant with forage pearl millet being associated with higher above ground dry matter (6 Mg ha⁻¹) and the lowest being associated with winter rye/hairy vetch mixture. Red clover was associated with highest total N accumulation (145 kg N ha⁻¹) followed by forage pearl millet (113 kg N ha⁻¹) and lowest value with sorghum sudan grass/ verticillium resistant alfalfa (68 kg N ha⁻¹). No effect of manure or cover crop was observed on total earthworm but a trend toward higher total number was observed under sorghum sudan grass. Forage pearl millet was associated with highest C accumulation in above ground biomass (2665 kg ha⁻¹) and lowest value was found in winter rye/hairy vetch mixture (1187 kg C ha⁻¹). Preliminary results suggest that forage pearl millet may represent a novel high residue potato rotational crop while being a good source of nitrogen.

Preferred Platform: Poster Presentation

Student Presenter: No

Impacts of Electrical Tower Construction on Soil Microbial Communities in Mixedgrass Prairies of Alberta

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The Eastern Alberta Transmission Line established by ATCO from 2014-2015 runs across 485 km of S. Alberta and has resulted in large-scale landscape changes across the mixedgrass prairies (MGP). The negative impacts of electrical transmission line construction may be alleviated through the use of access mats (AM) under tower construction sites to create a level work platform, compared to removal and stockpiling of soil during tower construction. Our objectives were to assess the potential of AM to decrease grassland disturbance and promote subsequent grassland recovery compared to traditional soil stockpiling techniques, and to contrast changes in the diversity, community structure, and size of soil microbial communities to understand the role of these communities in facilitating MGP recovery. Soil was collected along transects under tower construction sites using either traditional high disturbance (HD) construction techniques (UN) or low disturbance (LD) techniques using AM and from paired natural vegetation control areas (CON) at each tower site in July 2016. Soil DNA was extracted and used to target bacterial, archaeal, and fungal genes via qPCR and next-generation sequencing (Illumina Miseq) (n=8). At loamy sites, LD methods increased the size of bacterial and archaeal communities, but decreased fungal community size; similar results were not observed on sandy LD sites. HD methods significantly decreased fungal community size but did not influence bacteria or archaea. Nonmetric multidimensional scaling and perMANOVA indicated statistical differences in microbial communities based on construction methods and soil texture, particularly both construction methods on fungal communities, indicating their increased sensitivity to disturbances. In the context of fungal contributions to ecosystem functioning and soil carbon storage, these results highlight the need for a systems-level approach to ecosystem restoration when disturbing valuable areas such as the MGP.

Preferred Platform: Poster Presentation

Student Presenter: N

Predicting Soil Organic Carbon Sequestration Potential in Degraded Agricultural Soils

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Soil organic carbon (SOC) is a vital component of soil health. About 1.6 MHa of southern Ontario soils have become eroded or are moderately or very highly susceptible to further SOC loss from vulnerable landscape positions through water and tillage erosion. Productive soils have a ceiling or capacity to store SOC, and this ceiling is related to the clay concentration since it acts as a major component in the physical and biochemical protection from decomposition. We can predict the potential to re-gain C in soil landscape positions that have lost soil C by determining the maximum capacity or saturation of C in healthy soils. In this study we measured SOC in multiple commercial farms, at numerous landscape positions. Digital elevation models derived by LiDAR allowed for precise allocation of landscape units. Utilizing these models, the deficit of SOC and predictions of erosion risk in degraded landscapes the net potential to re-gain SOC through management practices aimed at ameliorating these soils in Ontario was estimated.

Preferred Platform: Poster Presentation

Student Presenter: N

Climate Change, Management, Diversity, and Environment Affect Soil Carbon and CO₂: a Case Study in Saskatchewan, Canada

Taras E. Lychuk, Alan P. Moulin, Reynald L. Lemke, Roberto C. Izaurralde, Eric N. Johnson, Owen O. Olfert, Stewart A. Brandt

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The relative concurrent impact of climate change, agricultural inputs, cropping diversity, and environment on soil organic carbon (SOC) and CO₂ emissions has seldom been assessed in the scientific literature. This modeling study assessed SOC and CO₂ emissions from microbial respiration (CO₂-MR) simulated with the Environmental Policy Integrated Climate (EPIC) model for historical weather (1971-2000) and future climate scenarios (2041-2070) for the Alternative Cropping Systems (ACS) study research site in Saskatchewan, Canada. Eighteen years of field and crop management information from the 1994-2013 ACS study were input to the EPIC model. The ACS study consisted of three levels of agricultural inputs [organic (ORG), reduced (RED), and high (HI)] and three levels of cropping diversity [low (LOW), diversified annual grains (DAG), and diversified annual & perennial (DAP)]. Changes in future SOC and CO₂-MR under climate change were explored with recursive partitioning in multivariate analyses of inputs, diversity, growing season precipitation (GSP), and growing degree days (GDD) and terrain attributes (TA). Under climate change, SOC decreased by 1.3% (from 132.3 to 130.6 Mg ha⁻¹) of original stocks in the 0-90 cm. Emissions were affected by climate change and increased by 17% (from 1.92 to 2.25 Mg ha⁻¹). Precipitation in May accounted for 16% of total variation in SOC. June temperature accounted for 9% of variation in CO₂-MR. The combination of input and cropping diversity was correlated with 3 and 7 percent of variation in SOC and CO₂-MR, respectively. The combination of RED inputs and DAG diversity increased SOC and reduced CO₂ fluxes under climate change relative to organic and conventional systems.

Preferred Platform: Oral Presentation

Student Presenter: N

CSSS_03: Wetland biogeochemistry and soil microbiology

Conveners: Aneta Bieniada¹, Saraswati Saraswati¹, Michael Carson²

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Methanogenic and methanotrophic communities in extracted and restored peatlands

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Presented research is a part of a project focused on CH₄ dynamics in a complex of extracted and restored peatlands. Two elements of CH₄ dynamics - production and oxidation - are microbial driven processes often overlooked in studies of greenhouse gas emission from disturbed peatlands. The study site is located in Seba Beach, AB and includes a natural bog (SBN), an unrestored (SBU) and an active (SBA) sites and peatlands restored in 1991, 2009, and 2012. The aim of the study was to characterize methanogenic and methanotrophic community profiles in studied peatlands with respect to the treatment (restored, unrestored, active), vegetation type, age of restoration, and compared to the reference SBN site. Eleven 1 m long peat cores, targeting main vegetation cover types (e.g., sedgy, mossy), were cut to 10 cm segments representing different depths within the water table fluctuation zone. Illumina tag sequencing of 16S rRNA was used to obtain bacterial and archaeal community profiles. Additionally, C/N ratio, DOC, acetate, other organic acids, and terminal electron acceptors (TEAs) were determined. Methane production and oxidation rates were measured in microcosms containing peat from above and below water table. We asked: Are there specific community members dominating only at restored or unrestored peatlands? Does the abundance and composition of microorganisms that outcompete methanogenesis vary at these sites? Is there a link between microbial abundance and the availability of organic acids, TEAs, and the quality of organic matter? We hypothesize lower diversity of microbes in unrestored and active sites but higher availability of TEAs due to large fluctuation of water table that may trigger reactions outcompeting methanogenesis. Dominating microorganisms varied with depth and between treatments, with vegetation type also influencing community profile. Relationships between local chemical conditions and microbial community will also be discussed.

Preferred Platform: Oral Presentation

Student Presenter: Y

Soil Organic Matter Decomposition: Tea and Litter Bag Analysis, and the Inhibitory Effects of Phenolic Compounds

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Fen reclamation following oil sands development has not been fully achieved. Critical to fen reclamation is the formation of peat, which occurs when biomass accumulation exceeds soil organic matter decomposition. The low decomposition rate found in peatlands has been attributed to various environmental conditions, including low pH, high moisture content, cool temperature and local chemistry, which ultimately dictates microbial activity and subsequent decomposition. To assess decomposition rates across a recently reclaimed fen, the Tea Bag Index and Litter Bag techniques were utilized. Results indicate that the decomposition rate is higher under treatments of *Carex aquatalis* as compared to *Juncus balticus*. In addition to moisture content, this rate may also be dependent on the inhibitory effects of phenolic compounds, and is largely referred to as the 'Enzymatic Latch'. Phenolic compound concentrations were assessed from water samples obtained from each location to determine their role on the decomposition rate. Preliminary results suggest that higher phenolic compound concentrations may be responsible for the lower decomposition rate found under *Juncus* treatment plots. For future fen reclamation projects, it may be advantageous to reclaim with *Juncus* species to minimize decomposition and enhance peat formation.

Preferred Platform: Oral Presentation

Student Presenter: Y

Biogeochemical Cycling of Carbon in Forested Wetlands, Southwest Nova Scotia

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Forested wetlands are unique ecosystems that are characterized by the dominance of large mature trees. This study aimed at characterizing the ecological role of forested wetlands as a carbon source or sink in relation to climate change. This was addressed by determining: 1) carbon (C) inputs via litterfall, 2) soil C pools, and 3) C outputs in the form of CO₂ and CH₄ in three forested wetlands plots that were paired with three adjacent upland forest plots and three edge plots (forested wetland-upland forest edge) in southwest Nova Scotia. The forested wetlands plots were associated with large supplies of C inputs (102.8 kg ha⁻¹ week⁻¹) through litterfall from the tree cover. There was substantially greater soil organic C stored in the wetlands soils (310609 kg ha⁻¹) than the upland forest soils (76290 kg ha⁻¹). The wetland soils had about 3.4 times more organic content (kg ha⁻¹) and about 4.1 times more total C content (kg ha⁻¹) as compared to adjacent upland forest soils. Forested wetland C-(CO₂ and CH₄) showed a moderate positive correlation with soil temperature and a strong negative correlation with soil moisture content. C-(CO₂ and CH₄) outputs (22.43 kg ha⁻¹ week⁻¹) were small in comparison to C inputs through litterfall (102.8 kg ha⁻¹ week⁻¹). The C input via litterfall were found to exceed the C output via greenhouse gas (GHG) emissions in the wetlands by a factor of about 4.6. Under a scenario of doubled C losses as GHGs due to climate change, the litterfall inputs would exceed these outputs by a factor of about 2.2. The findings of this study indicate that the unique ecosystems of forested wetlands can serve as a C sink despite a scenario of doubling GHG emissions. This distinguishes forested wetlands from other wetland types and supports conservation efforts aimed at preserving such ecosystems as a measure to mitigate climate change.

Preferred Platform: Oral Presentation

Student Presenter: Y

The stoichiometry of carbon, hydrogen and oxygen in peat

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Carbon (C), hydrogen (H) and oxygen (O) form ~90% by mass of peat, a product of the input of plant tissues and litter and the output of decomposition under aerobic and anaerobic conditions. We examined patterns of these elements, as the O:C and H:C atomic ratios, in over 1300 peat samples collected from over 400 profiles in Ontario, representing bogs, fens and swamps. The overall O:C ratio decreased from the surface (0.6 to 0.7) to ~0.5 at a depth of 50 cm and showed little change to a depth of 5 m. In contrast, the H:C ratio decreased only slightly (1.30 to 1.25) over the top 1 m and there was no further significant decline with depth. The carbon oxidative state (Cox) and oxidation ratio (OR) showed strong decreases and increases, respectively, with depth with most changes occurring in the top 1 m. The O:C ratio, and Cox and OR values, were significantly correlated with the von Post Humification Index, with most changes occurring in Index values 1 through 4, the latter representing a Collation of the Ontario peats with other data sets revealed the very large range in O:C and H:C values, with a general decrease from temperate to tropical and sub-tropical peatlands. Based on the O:C and H:C ratios of input (litter) and output (e.g. mineralization to CO₂, methanogenesis to CH₄ and CO₂ and loss as dissolved organic carbon) one can estimate the degree of decomposition as C loss.

Preferred Platform: Oral Presentation

Student Presenter: N

Effects of increased atmospheric reactive nitrogen deposition upon rates of biological nitrogen fixation in peatlands

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Biological nitrogen fixation (BNF) by diazotrophic microbes including cyanobacteria represents the natural pathway by which mosses (*Sphagnum* spp) meet the demands for reactive nitrogen (Nr) in pristine rain fed peatlands. However, during the last century, there has been an increase in atmospheric Nr deposition due to a growth in fossil fuel burning and the use of agricultural fertilizers. Because BNF is an energy intensive process, it has been suggested that high Nr deposition loads (10 Kg N ha⁻¹ y⁻¹) can shut down BNF activity in peatlands as Nr availability is no longer limited. To evaluate if BNF slows and/or shut down under chronic Nr deposition, we measured BNF rates in three peatlands across an Nr deposition gradient in Britain exposed to different Nr deposition rates over decades (6, 17, 26 Kg N ha⁻¹ y⁻¹), and a peatland in Sweden under background Nr deposition (2 Kg N ha⁻¹ y⁻¹). BNF rates associated with the dominant mosses (*Sphagnum* spp) as well as bulk peat (0–15 cm) were determined by the ¹⁵N₂ direct assimilation method. According to the results, chronic Nr deposition did not suppress and/or shut down BNF. For example a British site receiving Nr deposition rates of ~17 Kg N ha⁻¹ y⁻¹ showed an average 1.2 times higher BNF than sites with Nr deposition of 6 Kg N ha⁻¹ y⁻¹. In general, moss-associated BNF rates were higher in mosses with a higher tissue C:N ratio, and under a higher moisture content. Species inhabiting hollow exhibited significantly higher BNF rates than those inhabiting hummocks. Although significant differences in available N were found in pore water and peat between sites, it did not have a direct effect on BNF rates. Our results show that moss-associated BNF does not completely shut down under chronic Nr deposition and that this process can only be threatened by competitive takeover of mosses in peatlands by non-fixing vascular plants. This BNF contribution needs to be accounted for when modelling the N economy of peatlands.

Preferred Platform: Oral Presentation

Student Presenter: Y

Impacts of access roads on enzyme activities of boreal forested peatlands

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Canadian boreal forest is interspersed with both forested and open peatlands, mostly bogs and fens, that have a significant carbon stock (~550 Gt) in the form of peat and biomass. The carbon is stored due to low decomposition rate favored by low enzymatic activities (phenol oxidase and hydrolases), low pH, high water table, anoxic conditions and phenolic material accumulation. In peatlands, oxygen limitation to phenol oxidase can reduce phenolic material degradation, and the accumulated phenolics suppresses hydrolase activities – the process is known as the ‘enzymatic latch’ mechanism. However, the mechanism can be altered by construction of road networks for the exploration and extraction of natural resources (e.g. forest products, oil sands, and natural gas). To understand the impacts of roads on peat enzymatic activities, in 2016, we collected 39 peat samples each from a forested bog and a fen peatland near Peace River, Alberta. Average hydrolase activities in fen were □ four times higher than the bog. Two-way interactions of distance from road and culvert distance, and the road distance and side of the road had significant controls on phenol oxidase and sulphatase activities in the bog. Hydrolase enzyme activities were significantly higher on the downstream side of the road compared to the upstream side in the bog. Glucosidase activities were significantly impacted by the culvert distance in the bog. Moreover, enzyme activities were negatively correlated with the phenolic concentration, water table position, and pH. In contrast, the enzyme activities did not vary significantly in fen as the flow of water was not perpendicular to the road, which resulted in no significant variations in the water table, phenolics or pH with respect to the road associated factors. This research indicates that road fragmentation in boreal peatlands can alter enzyme activities and may ultimately increase decomposition rates and CO₂ emission.

Preferred Platform: Oral Presentation

Student Presenter: Y

Effects of long-term fertilization on dissolved matter in an ombrotrophic bog

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An 18-year fertilization study at the Mer Bleue ombrotrophic bog has investigated impacts of elevated nitrogen (N), phosphorus (P), and potassium (K) inputs on ecosystem functioning. There is a dearth of knowledge regarding the relationship between porewater chemistry and treatment thus in 2017 we examined porewater dissolved N, P, and carbon (DOC) in response to ammonium nitrate + potassium phosphate (NPK-plot), ammonium nitrate (N-plot), sodium nitrate (NO₃-plot), and ammonium chloride (NH₄-plot) fertilization at 6.4 g N m⁻² yr⁻¹. Samples were collected in the rhizosphere (15 cm) and below the water table (45 cm) 3 times within the fertilization period (May to August) and once afterwards (October). Samples were analyzed for N (DON, NH₄⁺, NO₃⁻), P (dissolved organic P and orthophosphate), DOC, and SUVA. We anticipated an increase in nutrient concentrations, relative to the controls, as well as an increase in DOC and SUVA, in response to shifts in vegetation. A significant increase in NH₄⁺ was observed in all treatments and NO₃⁻ increased in all treatments except NH₄-plot ; DON increased significantly in the NPK-plot and N-plot treatments and decreased in NH₄-plot. An increase in PO₄⁻ and DOP was observed in NPK-plot (attributed to treatment) and N-plot (attributed to peat decomposition). A decrease in DOC was observed in NH₄-plot and evidence of increased aromaticity from SUVA₃₆₅ and absorbance ratios was observed only in NPK-plot. Because of the dry post-fertilization period, the patterns persisted 6 weeks after fertilization ceased in 2017. These results show that peat porewater is sensitive to nutrient addition, differentially between the rhizosphere and the water table, which may impact interactions between plants, microbes, and peat and in turn greenhouse gas emissions.

Preferred Platform: Oral Presentation

Student Presenter: Y

Peat nitrogen pools and N₂O emissions

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Nitrous oxide is a greenhouse gas that is both produced and consumed by soil microorganisms. The soil pools of NO₂⁻, NO₃⁻, NH₄⁺ and other compounds are transformed into N₂O by nitrifying and denitrifying organisms responding to environmental conditions that are primarily controlled by water content in peat. Nitrogen inputs to peatlands come from in situ nitrogen fixation, from atmospheric deposition, and from groundwater in fens but not in bogs. Two restored peatlands in Alberta were chosen to examine the effects of restoration on components of the nitrogen cycle and contributions to total greenhouse gas emissions from N₂O. Both peatlands were most likely fens prior to disturbance by oil-extraction activities in the form of well pads to support drilling in the oil sands region of northern Alberta. Subsequently, a range of techniques have been employed with the goal of returning these ecosystems to peatland vegetation communities with ecosystem functions similar to surrounding peatland peatlands. We measured concentrations of NO₂⁻ and NO₃⁻ (combined) and NH₄⁺ in peat cores collected from treatment sites at the two well pads. Subsamples from 30 cm deep cores were taken from just below the living plants and at the bottom of the core to compare nitrogen pools under conditions of assumed generally high oxygen availability at the top and very low oxygen availability in peat at the bottom that was below the water table most of the time. Each core was associated with a greenhouse gas flux measurement plot monitored throughout the summer for fluxes of CO₂, CH₄, and N₂O, allowing comparisons between peat N pools and atmospheric exchanges. Compared to agricultural landscapes, little N₂O was produced at these peatlands, yet the amounts of N compounds detected in the peat suggest considerable potential for emissions that would offset the considerable carbon-sequestration capacity of these ecosystems and may have implications for vegetation succession during restoration.

Preferred Platform: Poster Presentation

Student Presenter: N

Culturing techniques in the age of omics: Strategies for obtaining uncultured soil microorganisms and genomes from environmental samples

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Rapid advancement in sequencing capabilities and reduction in cost has increased the use of omics based research approaches, however, with these advancements there is presently an information gap forming between omic based and community fingerprinting approaches and traditional culturing studies. Here we anaerobically enriched peat soil with growth substrates, supplements, and antibiotics to identify novel methanogen taxa and potential growth conditions. Over the course of three years we identified 28 taxa (via *mcrA* sequences) that have remained previously uncultured and undescribed beyond distantly-related sequences detected in environmental samples. Evidence suggests that novel methanogens, representing 5 of the 7 known orders, were capable of growing on H₂ as well as acetate and at temperatures ranging from 6 °C to ca. 22 °C. Methods involving the use of ampicillin proved useful and obtaining high methane production in the absence of H₂ was difficult. Our results also indicate that many methanogens may rely on bacterial symbionts (commonly *Clostridium* spp.) and that enrichments are a useful intermediary between marker-gene detection and isolation, allowing us to broaden our understanding of methanogen physiological ecology, while bolstering our reference sequence library to support the plethora of *mcrA* and rRNA gene based community-fingerprinting studies. Due to the relative difficulty in isolating anaerobic microorganisms, and methanogens in particular, we propose that combining enrichments and modern sequencing methods are a way forward in developing an understanding of methanogen diversity and functioning in a variety of ecosystems, effectively bridging the gap between environmental omic based approaches and traditional culturing techniques.

Preferred Platform: Poster Presentation

Student Presenter: Y

The 'Priming Effect' of *Carex aquatilis* and *Juncus balticus* During Fen Reclamation

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Peatlands accumulate organic matter due to biomass exceeding soil organic matter decomposition. Approximately 88 000 km² of the Athabasca Oil Sands Region is overlain by fen peatlands, which oil sands companies are legally responsible to reclaim to equivalent land capability. However, large costs and a lack of efficient techniques have made it difficult to restore these disturbed areas to their former peat accumulating function. The low decomposition rate found in peatlands can be attributed to various environmental conditions, however microbial activity is ultimately responsible for this rate. High plant productivity leads to an abundance of labile biomass that may enhance microbial activity, resulting in the 'Priming Effect' and leading to an induced decomposition rate. An incubation experiment was conducted to investigate the decomposition dynamics of peat, *Carex aquatilis* and *Juncus balticus*, as well as typical reclamation amendments of wood-strand mulch and straw. The experiment was conducted under both aerobic and anaerobic conditions, and yielded mix results. *Carex* has been shown to decompose faster than *Juncus* species, and more recalcitrant organic matter like peat and wood are assumed to be more resistant to degradation as compared to the more labile species of sedges and straw. Almost all of the treatments under anaerobic conditions showed some evidence of priming, while the majority of treatments under aerobic conditions did not. Samples of the substrates and headspace were submitted for $\delta^{13}\text{C}$ analysis, and an end member mix analysis was performed on the double treatments to determine the primary sources of CO₂ during microbial respiration. Treatments with peat and *Juncus* showed the majority of CO₂ came from peat, while amendments with straw and wood were the primary sources for the remaining treatments. The results from this study could be used as recommendations for future species selection during fen reclamation.

Preferred Platform: Poster Presentation

Student Presenter: Y

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

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Peatlands 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 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 burned portions play a key role in fixing the excess nutrients in bioavailable pools, however, there is a threshold level that needs to be met before vegetation and microbes can return to normal function. 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.

Preferred Platform: Poster Presentation

Student Presenter: Y

CSSS_05: Agricultural impact on Canada's soil and water: Modelling, measurements and trends

Conveners: Keith Reid¹, Kimberley Schneider¹, Brian McConkey², Craig Drury³, David Lee⁴

Co-chairs: Keith Reid, Kimberley Schneider

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Pulse crop impact on total soil carbon, nitrogen and microbial composition in rain-fed wheat-based crop rotation in the semi-arid Canadian prairies

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Most annual crop producers on the Canadian Prairies diversify their wheat-based crop production systems by including pulse and oilseed crops. Pulse crops, such as field pea (*Pisum sativum*), chickpea (*Cicer arietinum*) and lentil (*Lens culinaris*) in crop rotations with cereals has gained interest among producers due to several rotational, environmental and economic benefits. Research on the impact of pulse crops on total soil carbon (C) and nitrogen (N), and microbial composition are limited. A study was conducted at Brooks, AB using chickpea, field pea and lentil as component crops, grown alternately with wheat, to examine the impact of these crops on total soil C and N, and microbial composition. One rotation included lentil and chickpea in rotation with wheat (lentil-wheat-chickpea-wheat). A continuous wheat treatment was also included for comparison purpose. Soils were sampled in the spring of 2017, after 6 years of the rotation were complete.

Results suggested that the lentil and chickpea grown alternately with wheat (W-L-W-C-W) had the highest total soil C percentage (1.30 %), and the lowest value (1.18 %) was observed from wheat/pea crop rotation in the top soil (0-15 cm). Chickpea alternating with wheat produced the highest total soil N (0.123 %) and the lowest value was noted from W-L-W-C-W (0.118%). The C:N ratio was significantly higher in the W-L-W-C-W (11.1) and lowest in wheat/pea crop rotation (10.0). At the 15- 30 cm depth, wheat/chickpea had the highest for both total soil C and N, and the lowest total soil C was produced by wheat monoculture whereas the total soil N by W-L-W-C-W crop rotation. The C:N ratio of the soil in the 15- 30 cm was highest in the W-L-W-C-W crop rotation (10.6) whereas wheat/pea crop rotation had the lowest (7.9). The soil microbial composition analysis using Phospho-Lipid Fatty Acid (PLFA) is in progress. The improved C:N ratio in W-L-W-C-W rotations probably due to a lower level N contribution to soil and also a slower decomposition/mineralization rate of the residues. An incubation study examining mineralization rates will verify if this is the case.

Preferred Platform: Oral Presentation

Student Presenter: Y

Trends in phosphorus accumulation in Ontario agricultural soils: Updates to the cumulative P balance in the indicator of risk of water contamination

Keith Reid, Pamela Joosse, Bruce MacDonald, Kimberley D Schneider

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The accumulation of P in agricultural soils is one of the drivers of P loss, as higher levels of labile P equate to greater dissolved P concentrations in runoff water. This accumulated P also represents the agricultural portion of legacy P, which can continue to release P for years or decades. Soil tests can provide this information, but these values are not readily available to policy makers or NGOs who might be interested in this information, so cumulative P balance is calculated from census data as a proxy. The P balance model has been updated to account for fertilizer and livestock manure P inputs prior during the 1960s and '70s, and the allocation of fertilizer to crops has been improved. Trends in P accumulation in Ontario soils will be discussed, including the correlations between the model predictions and the average soil test values from representative counties across Ontario.

Preferred Platform: Oral Presentation

Student Presenter: n

Nutrient loss in snowmelt runoff: A case study from the Canadian Prairies

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Snowmelt runoff often comprises the majority of annual runoff in the Canadian Prairies and thus also represents a significant proportion of total nutrient loss from agricultural soils to surface water. Runoff volume and nutrient losses from a long term runoff experiment (at Swift Current, SK) with field-scale side by side runoff watersheds were analysed for the years 1996-2011. Initial results from a broad comparison of the watersheds which included different treatments (conventional tillage, zero-tillage, and organic management) show that within the range of soil nutrient concentrations found in these soils, runoff volume is the dominant factor affecting nutrient loss. The ability of prediction equations (including those used in AAFC's IROWC-P) to accurately predict P loads in snowmelt runoff was also examined and revealed that prediction equations work well for fallow fields but are more variable for those with crop stubble. The importance of green manure as a contributor to nutrient loss in snowmelt dominated runoff systems is also indicated.

Preferred Platform: Oral Presentation

Student Presenter: n

The Indicator of risk of water contamination by phosphorus (IROWC-P): Model improvement, initial validation, and applicatio.

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In Canada, phosphorus (P) from agricultural sources has been implicated as an important contributor to algal blooms in many shallow lakes, including Lake Erie, Lake Simcoe, Lake Winnipeg and Lake Champlain. There is a need to assess the risk of P loss from agricultural land in a way that takes into account agricultural sources of P, agricultural system management, as well as unique physiographic features of the landscape that affect P transport. To address this need, the Indicator of Risk of Water Contamination by Phosphorus (IROWC-P) was originally developed by Agriculture and Agri-Food Canada using principles similar to the P Index which is used at the field scale in most US states. New data on P risk assessment and P loss that has come available has provided the opportunity to update the both the model structure and the science behind the algorithms that are used to operate IROWC-P. This presentation will explain the latest updates to IROWC-P, including adding tile drainage and crop leaching components, as well as present initial model validation data. Sources of model input data will be summarized highlighting future data needs. Finally, the potential application of IROWC-P, including use by government and industry to model potential scenarios and the impact of changing management practices will be discussed.

Preferred Platform: Oral Presentation

Student Presenter: n

A new lysimeter facility for the study of soil ecosystem services provided by diverse cropping systems

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Diversifying annual crop rotations is a strategy that mimics natural ecosystems and is postulated to increase agricultural resilience to climate change, soil quality and provision of soil ecosystem services. However, diverse cropping systems could increase soil mineral N levels and lead to greater leaching and/or N₂O emissions; which raises the questions: (i) are diverse cropping systems actually beneficial for air and water quality? (ii) what are the trade-offs between soil, water, and air quality upon implementing a diverse cropping rotation? We are addressing these questions using a newly-funded soil lysimeter infrastructure by quantifying the role of agri-food practices on the amount, fate, and pathway of nitrogenous contaminant loss, and linking contaminant loss to soil microbial community structure (an indicator of soil health). The infrastructure is comprised of high-precision weighing lysimeters, nine for each of two soil types (silt loam, sandy loam), instrumented with automatic gas chambers coupled to a trace gas analyzer. A sub-set of lysimeters are being subjected to winter warming. An overview of the experimental site and planned experiments will be given. Preliminary results characterizing the variability within soil type will be presented and results from the two contrasting soil types will be discussed.

Preferred Platform: Oral Presentation

Student Presenter: N

Impact of Soil Amendments on Field Hydraulic Conductivity of Loamy Sand Soils in Western Newfoundland

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Soil hydraulic properties are the basis for understanding flow and transport processes in the vadose zone. In addition, hydraulic properties of surface soils influence the partition of input water (by precipitation / irrigation) into runoff and soil water storage, and are altered with the use of soil amendments in agricultural soils. This study focused on field unsaturated (Kunsat) and saturated (Ksat) hydraulic conductivity of agricultural soil with an emphasis on amending the soil with dairy manure (DM) and biochar (BC). The study was conducted at Pynn's Brook Research Station (49°04'22.6"N 57°33'38.9"W), Department of Fisheries and Land Resources, Government of Newfoundland and Labrador, Canada. The soil is classified as loamy sand (73.7±4.1 % sand + 23.0±3.8 % silt + 3.3±0.3 % clay). The BC (Air terra soil matrix) was produced using yellow pine wood (*Pinus taeda*) by slow pyrolysis at 550°C. DM and BC were incorporated up to 20 cm depth at a rate of 30,000 L/ha and 20 t/ha, respectively. The experimental design was randomized complete block and the plots were planted with silage-corn (*Zea mays*) and not irrigated. The treatments were; control without amendment (0N), inorganic N fertilizer (IN), two types of DM (DM1 and DM2), BC and DM1+BC. Infiltration data were collected with a minidisk tension infiltrometer (decagon devices) under two suction levels (2 cm as unsaturated and 0.1 cm as near saturated conditions). Kunsat was calculated according to Zhang (1997). The data were analyzed with general linear model (GLM) at 5% probability. There was no significant effect of DM and BC on Ksat. BC was observed to have no considerable influence, while DM 1, DM 2 and DM 1+BC had significantly lower Kunsat under 2 cm suction ($p=0.009$, 0.002 and 0.031 , respectively) compared to the control. Since these soil amendments can influence soil hydrology such as reduced infiltration and increased surface runoff, carefully monitored agronomic practices are recommended.

Preferred Platform: Oral Presentation

Student Presenter: Y

Changes to soil microbial phospholipid fatty acid profiles with long-term crop rotation and tillage practices

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Agricultural management plays an important role in altering soil microbial biomass and composition in agroecosystems. However, little is known about the long-term impact of crop diversity and tillage on soil microbial abundance and community composition. Changes to the soil microbial community may also alter soil carbon cycling and turnover in agroecosystems. A long-term crop rotation trial established in 1980 at the Elora Research Station, Ontario, provided the opportunity to assess the impacts of crop diversity and tillage practices on microbial communities. This experiment includes crop rotations ranging from continuous monoculture to four species diversities under conventional tillage (CT) using moldboard plow and no-tillage (NT) practices. Microbial phospholipid fatty acid (PLFA) profiles of the upper 10 cm of soil show that in lower crop diversity treatments including continuous corn and corn-corn-soybean-soybean, concentrations of bacterial and fungal PLFAs of NT are higher than those of CT; while in higher crop diversity treatments, bacterial and fungal PLFA concentrations appear to be similar under the two tillage practices. No significant difference in bacterial/fungal PLFA ratio was observed between all the treatments except continuous alfalfa under CT that had a lower ratio than in other treatments. Continuous alfalfa has higher bacterial and fungal PLFA concentrations compared to other low crop diversity rotations under the same tillage, which may indicate that this plant species alters soil carbon cycling in a unique manner. These results suggest that changes in diversity of crop rotation and tillage practices are strongly related to soil microbial biomass. This data will be combined with results of plant biomarkers, carbon/nitrogen ratio and nuclear magnetic resonance data to assess the link between alteration in soil organic matter and microbial biomass under various land practices.

Preferred Platform: Poster Presentation

Student Presenter: Y

CSSS_06: Tightening nitrogen cycle for more resilient agricultural systems

Co-chairs: Mehdi Sharifi¹ and Judith Nyiraneza²

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Modeling and scaling up of gaseous nitrogen loss from corn production systems of Ontario

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Nitrogen (N) is the single most expensive agricultural input for corn production systems in Ontario. Despite significant field and modeling efforts, N use efficiency remains low while excessive N loss in air and water is often linked to environmental degradation. In this study, we applied the DNDC model for 270 distinct soil-climate-crop regions to quantify yields and gaseous N loss in the form of nitrous oxide (N₂O) and ammonia in response to seven fertilizer management scenarios for corn systems in Ontario. We obtained soils information from the Soil Landscapes of Canada database and weather for each soil unit was generated based on the North American Daily Surface Weather Dataset. This study addresses the need for an improved modeling platform and a baseline for provincial scale reduction in gaseous N loss following adoption of 4Rs by corn producers. Our results will further benefit policy analysts, producers, and the fertilizer industry to prioritize the most effective management practices for corn production across agricultural soils in Ontario.

Preferred Platform: Oral Presentation

Student Presenter: N

Modelling crop rotation effects on inorganic nitrogen transport through soil profile

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Modelling the transport of inorganic nitrogen forms through soil profile can be used to quantify crop rotation effects on mineral N fate and transport in soil profile. This study aimed to evaluate the effects of three crop rotations including wheat-corn, wheat-fallow and wheat-rice on the mobility of nitrate (N-NO_3) and ammonium (N-NH_4) through soil profile. In each crop rotation, soil samples were taken from three depths (0-30, 30-60 and 60-90 cm) after each irrigation or rainfall, in total at seven sampling date and analyzed for nitrate and ammonium. The simulation of ammonium and nitrate mobility was performed by HYDRUS1-D code. The results showed that the rotation type had a significant effect on soil nitrate profile through its effects on soil hydraulic characteristics. Soil hydraulic parameters were different in three rotations. Soil nitrate concentrations in wheat-corn rotation were significantly greater than the other rotations; while wheat-rice rotation profile had the lowest nitrate concentrations. Comparison of nitrate and ammonium concentrations in different times and depths showed that ammonium concentration was much lower than nitrate. The simulation results indicated that HYDRUS-1D model could predict successfully nitrate ($\text{RMSE} = 0.07$, $\text{R}^2 = 0.95$) and ammonium ($\text{RMSE} = 0.13$, $\text{R}^2 = 0.721$) dynamics in soil under the three rotations.

Preferred Platform: Oral Presentation

Student Presenter: N

Reducing ammonia and nitrous oxide emissions using urease & nitrification inhibitors and improved N placement methods

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The 4R strategy has been proposed as a best management practice to reduce nitrogen losses from soils especially when precipitation can vary dramatically between growing seasons. We compared two application times (planting versus sidedress) and 3 application methods (broadcast urea, broadcast and incorporated urea or injected UAN) with/without a urease inhibitor or a combination of urease and nitrification inhibitors on N losses and corn yields. Broadcast and incorporated urea reduced N losses compared to broadcast urea but UAN injection reduced N losses the most of the 3 application methods. Corn grain yields were 15% greater with the sidedress injection of UAN compared to applying broadcast urea at planting. Hence using inhibitors and improved fertilizer placement can reduce nitrogen losses to the environment and increase yields and profitability.

Preferred Platform: Oral Presentation

Student Presenter: n

Cover cropping as a strategy to reduce over-winter nitrogen loss from fall-applied manure

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Approximately 35% of animal manure is fall-applied during the post-harvest period in Canada. Without an actively growing crop in the ground, the nitrogen (N) input from the fall-applied manure is susceptible to over-winter losses, especially following freeze-thaw events. A fall-sown cover crop that uptakes and retains N from fall-applied manure may reduce over-winter N losses, but this needs to be confirmed in field crop systems that are harvested in late fall (after mid-September). The objective of our study is to determine in a field system how fall-applied N from manure and cover crop treatments is retained in the soil-plant system over winter and subsequently used by a spring cereal crop. The field experiment is a full factorial with three manure (none, liquid and solid) and four cover crop (none, grass, and two different grass/legume bi-cultures) treatments, and is implemented at two field sites after soybean (*Glycine max* L.) was harvested in the third week of September. The quantity of N in the applied manure, the soil organic N stock, and the retention of N in cover crop biomass (shoots and roots) are determined in the fall (“fall N stock”) and compared with the quantity of N recovered in the soil and cover crop biomass in the spring (“spring N stock”) to create a partial N mass balance. Following cover crop termination, spring wheat (*Triticum aestivum* L.) is planted. Biomass and N content are taken at 3 key growth stages (tillering, booting, and flowering) during the season, followed by overall wheat yield and N uptake at harvest. The retention of applied manure N in cover crop biomass over winter, and subsequent availability to the wheat crop, will be discussed.

Preferred Platform: Oral Presentation

Student Presenter: Y

Legacy Effect of Cattle Manure Application on Greenhouse Gas Emission

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Beef cattle feedlot manure is often applied to land near the feeding operations. However, long-term manure application may lead to nutrient and carbon loading in the soil, increasing the risk of loss to the environment. This study compared greenhouse gas emissions from a field that received the first manure application in 1973, and has a 43 year history of manure applied at 0 and 60 Mg ha⁻¹ yr⁻¹, synthetically fertilized soil, and soil that received 14 and 30 annual manure applications followed by 29 and 13 years with no manure application (discontinued), under rainfed and irrigated conditions in semi-arid southern Alberta. Greenhouse gas emissions were measured for one year following manure application in autumn 2015, and soybeans were grown during the 2016 growing season. Forty-three annual manure applications led to higher ($P < 0.05$) CO₂ and N₂O emissions than non-amended soil, synthetically fertilized soil and the soil with discontinued manure applications. Soil CO₂ and N₂O emissions from discontinued manure applications, synthetically fertilized and non-amended soil were not different. Irrigated soil that received 43 annual manure applications emitted more CO₂ and N₂O than the rainfed soil receiving continuous manure. However, irrigation did not alter soil CO₂ and N₂O emissions for the non-amended and synthetically fertilized soil. Irrigated soil that received 43 annual manure applications was a small CH₄ source, while all other treatments were CH₄ sinks. The higher CO₂ and N₂O emissions after 43 annual manure applications, especially under irrigated conditions, corresponded with higher water-extracted soil organic C and NO₃ concentrations. After manure application was discontinued, gas emissions were similar. The results suggest that available soil C and N were respired by microbes and taken up by plants at levels similar to non-amended and synthetically fertilized soil. A second year of data has been collected to further explore the potential legacy effect.

Preferred Platform: Oral Presentation

Student Presenter: N

Quantifying soil N₂O emission after soil thawing from manure-amended agroecosystems with fall-sown cover crops

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Nitrous oxide (N₂O) emissions from agroecosystems have a negative environmental impact, owing to their contribution to global warming and stratospheric ozone depletion. In cold climates, peaks of N₂O emission from agroecosystems are associated with freezing-thawing cycles since snow melting creates anoxic conditions that are ideal for denitrification. The magnitude of N₂O emissions after soil thawing will be affected by the reactive nitrogen (N) concentration in the soil-plant system. The objective of this study was to quantify N₂O emission after thawing events in manure-amended agroecosystems and fall-sown cover crops. The experiment was established by applying three manure treatments (none, liquid and solid) to field plots in mid-September after soybean (*Glycine max* L.) harvest. Then, plots were either unplanted or sown with ryegrass (*Lolium multiflorum*) or a mixture of ryegrass/hairy vetch (*Vicia villosa*). The 3 x 3 factorial (manure x cover crop) experiment was applied to replicate plots (28 plots in total). Soil conditions and freezing-thawing cycles were monitored with soil temperature and moisture probes installed at two depths (5 and 15cm) and monitored with an automated weather station. During thawing events, N₂O is collected from non-steady state closed chambers and reactive N (ammonium and nitrate) is measured with ion exchange membranes. Relationships between N₂O emissions and reactive N during thawing events, as a function of manure x cover crop treatments, will be discussed.

Preferred Platform: Oral Presentation

Student Presenter: Y

Reduction of N₂O emissions from biosolids-amended soil in corn agroecosystems

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Biosolids from wastewater treatment is applied to corn fields as a fertilizer by farmers, and the influence of applied biosolids on N₂O emission is still unclear. Therefore, knowledge of the trade-offs between corn field N₂O emission and biosolids management practice is essential for the development of sustainable corn agroecosystems. The objective of this study was to evaluate the effects of different biosolids sources and their application methods on N₂O emissions in corn agroecosystems. A factorial field experiment was conducted at the Lods Agronomy Research Centre of McGill University near Montreal, Canada from May-Oct., 2017, with five treatments: alkaline treated biosolids (ATB), mesophilic anaerobic digested biosolids (MADB) and composted biosolids (CB), which were spread either with or without soil incorporation, plus fertilized control with urea and an unfertilized control. All treatments were replicated four times. The amount of fertilizers was adjusted according to their available N content to achieve N application rate 120 kg N ha⁻¹. Regardless of the biosolids treatment, comparatively higher N₂O flux occurred from 6 July to 16 August when soil moisture was low and air temperature was high. The fertilizer treatments had significant effects ($p < 0.05$) on N₂O emissions but incorporation did not. The lowest cumulative N₂O flux 168 $\mu\text{g m}^{-2} \text{h}^{-1}$ was from the unfertilized control followed by 345 $\mu\text{g m}^{-2} \text{h}^{-1}$ from the ATB, 496 $\mu\text{g m}^{-2} \text{h}^{-1}$ from the CB, 726 $\mu\text{g m}^{-2} \text{h}^{-1}$ from urea treatment and 1179.11 $\mu\text{g m}^{-2} \text{h}^{-1}$ from the MADB. Among fertilizer treatments, ATB had the lowest N₂O flux during 2017 growing season. Implications of using ATB as a N fertilizer source for corn will be discussed.

Preferred Platform: Oral Presentation

Student Presenter: Y

Can Cover Crop Residues Reduce Nitrogen Immobilization During Corn Stover Decomposition?

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Corn residues may impede soybean establishment or lead to temporary N deficiency during early soybean growth in corn-soybean rotations. An incubation experiment was established in a completely randomized design to evaluate the effects of cover crop residues with low C/N ratios on corn residue decomposition and N immobilization ($n = 216$). Soils from Ridgetown (clay loam; C/N = 13) and Peterborough (sandy loam; C/N = 13) were amended with, red clover (C/N = 12) or annual ryegrass (C/N = 15), corn stover (C/N = 70), and corn stover + cover crop residues at 0.7, 6.3, and 7 g C kg⁻¹ soil, respectively. Mineralized N and microbial biomass were evaluated at 3, 7, 14, 30, 60 or 98 d following incubation at 25°C. All corn-amended treatments produced net immobilization of N (-34 – -21 g N kg⁻¹) at 3, 7, 14, and 30 d. In both soils, red clover produced net N immobilization at 3 and 7 d (-17 g N kg⁻¹) but was comparable to the unamended and annual ryegrass-amended soils thereafter. Overall, annual ryegrass produced net N mineralization which was not different from the control in the clay loam. After 60 and 98 d of incubation, all treatments were not different from the control (sandy loam: 9 – 20 g N kg⁻¹; clay loam: -18 – 15 g N kg⁻¹). Microbial biomass C and N in the clay loam were significantly greater in the corn-amended (750 mg C and 90 mg N kg⁻¹) than the cover crop-only treatments or unamended control (369 mg C and 22 mg N kg⁻¹), while no significant differences were observed in the sandy loam. Findings suggest limited potential for annual ryegrass or red clover to curb N immobilization from corn residues. Carbon mineralization and non-linear regression results will also be presented.

Preferred Platform: Oral Presentation

Student Presenter: Y

Efficacy and stability of a novel urease Inhibitor in reducing ammonia volatilization from urea-based fertilizers

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Urease inhibitor formulations containing N-(N-butyl) thiophosphoric triamide have been reported to effectively reduce ammonia volatilization from urea-based fertilizers. Two greenhouse studies were conducted to evaluate the efficacy (study 1) and stability (study 2) of a novel urease inhibitor (ARM UTM) in reducing ammonia volatilization from urea and urea ammonium nitrate (UAN). Study 1 consisted of urea treated with and without ARM-U (applied at two rates) and two commercial urease inhibitors. Study 2 consisted of urea and UAN treated with and without ARM-U at 6, 3 and 0 months before the study. These treatments were broadcasted (100 kg N ha⁻¹) to soil in chambers from which ammonia volatilization were measured with acid charged discs at various times for 21 to 28 d. Daily ammonia fluxes followed the same pattern in urea treated with and without urease inhibitors in both studies. At the end of study 1, total ammonia volatilization (% of applied N) was 23% in untreated urea and 0.8 to 1% in urea treated with ARM-U. Total ammonia volatilization from urea treated with ARM-U was not significantly different from those treated with commercial urease inhibitors (0.9 to 1.2%). In study 2, total ammonia volatilization in untreated urea and UAN was 33 and 32%, respectively. The corresponding ammonia volatilization in urea and UAN treated with ARM-U ranged from 6.4 to 9% and 8.6 to 12%, respectively. There was no significant effect of time of treating urea and UAN with ARM-U on the efficacy of this urease inhibitor. We concluded that (i) ARM-U was as effective as other commercial urease inhibitors in reducing ammonia volatilization losses (ii) Urea and UAN can be coated or mixed with ARM-U six months prior to field application without compromising its effectiveness in reducing ammonia volatilization losses.

Preferred Platform: Oral Presentation

Student Presenter: Y

Ground cover, root zone management and irrigation system effects on soil mineral N dynamics in a newly established sweet cherry orchard

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Ground cover, root zone management and irrigation system have profound effect on soil nitrogen (N) supply in sweet cherry (*Prunus avium* L.) orchards. In a four year (2014-2017) study, soil mineral N (SMN) concentrations to 30 cm depth in different soil and water management treatments were measured in a newly established cherry orchard on a sandy soil in Summerland, BC. Soil treatments include (1) untreated soil (control), (2) fumigation at planting, (3) preplant incorporation of agricultural waste compost (AWC), (4) surface application of bark chip mulch after planting (BM), and (5) combined application of AWC and BM. All soil treatments were imposed to a 1.5 m wide band on the tree row under microsprinkler and drip irrigation. Compost and mulch were applied at 150 and 250 m³/ha orchard area, respectively. Both AWC and BM were reapplied to soil surface in 2016. All treatments were fertigated mid-season for six weeks with total 30 g N/tree and 15 g P/tree. Soil samples were collected in spring and late summer each year and soil mineral N was determined. The interaction among treatments and irrigation system was significant at each sampling date. Soil mineral N concentrations averaged across years, sampling date and irrigation in BM and BM+AWC (9.42 mg N/kg) were comparable or lower than control (14.0 mg N/kg), but always were lower than fumigation and AWC (17.1 mg N/kg). The SMN concentrations under BM+AWC treatment (5-10 mg N/kg) were more consistent compared with other treatments (3-36 mg N/kg). Environmental factors associated with year affect the magnitude of SMN, but the differences between treatments persisted. A pulse of SMN was observed in fumigated plots in the first year, but values were on par with AWC in subsequent years. In cherry orchards on sandy soils with low organic matter content, annual fluctuations in precipitation and water management are the main drivers of SMN in top 30 cm.

Preferred Platform: Oral Presentation

Student Presenter: N

Impact of long-term tillage and N fertilization on labile soil N pools in a soybean-corn rotation

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Tillage and N fertilization are known to significantly impact the productivity of agroecosystems. However, a greater understanding of their long-term and interactive influence on labile soil N pools is needed to implement sustainable soil and N management practices. Soil samples were collected at 0-5, 5-10 and 10-20 cm in the corn (*Zea mays* L.) phase of a long-term (24 yrs) soybean (*Glycine max* L.)-corn rotation in eastern Canada. The experiment was designed as a split-plot with two tillage practices [no-till (NT) and mouldboard plough (MP)] as main plots and nine combinations of N and P levels as subplots randomized in the main plots, with four replicates. Our study focused on plots that received 0, 80 and 160 kg N ha⁻¹ combined with 80 kg P ha⁻¹. We measured the concentrations of soil mineral N, water-extractable organic N (WEON), microbial biomass N (MBN), particulate organic N (POMN), mineral-associated organic N (Min_Assoc_N), and soil total N. Preliminary results show a significant tillage effect on all parameters, except soil mineral N, and a significant N rate effect on soil mineral N and WEON concentrations. There was stratification of POMN, Min_Assoc_N, MBN and soil total N under NT but not under MP. Further in-depth analysis of results and implications of this study will be presented and discussed.

Preferred Platform: Oral Presentation

Student Presenter: No

Nitrogen mineralization in sandy loam and silty clay soils receiving liquid swine and dairy cattle manure

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Liquid manures contain labile organic-N compounds that mineralize to supply N for crops, but how liquid manures affect transformations of labile soil organic-N fractions is poorly understood. The objective of this study was to monitor the dynamics of labile organic matter fractions: 1) microbial biomass N (MBN), 2) particulate organic matter N and C (POMN and POMC), 3) salt-extractable organic-N (SEON), as well as mineral-N ($\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$), apparent net manure organic-N mineralization (ANNM), and transformations of POM^{15}N in sandy loam and silty clay soils that received ^{15}N enriched liquid dairy cattle manure (LCM) or liquid swine manure (LSM). Manure-soil mixtures were aerobically incubated at 25°C for 98 d. An increase in mineral N concentrations coincided with a significant decrease in SEON and narrowing of the POMC:POMN ratio from 15.9 to 14.4 in the first 28 d. In the silty clay soil, LCM increased SEON and POMC more than LSM, but not ANNM or POMN. In the sandy loam soil, there was 7% more ANNM in LCM than LSM-amended soils. Since these soils had comparable microbial biomass, we postulate that labile organic-N was bound in organo-mineral complexes in the silty clay soil and thus physically and/or chemically protected from mineralization. This was supported by substantial depletion of the POM^{15}N fraction in the silty clay soil, but no concurrent increase in organic-N mineralization, suggesting that the intermediates released from POMN decomposition were protected from mineralization, likely building a pool of potentially mineralizable N.

Preferred Platform: Oral Presentation

Student Presenter: No

Impacts of Industrial Traffic on Soil Microbial Communities in Mixedgrass Prairies of Alberta

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Significant areas of the mixedgrass prairies (MGP) in Alberta have experienced heavy industrial equipment traffic due to infrastructure development, which may result in fluctuations in edaphic conditions that influence soil microbial communities. These impacts may be alleviated through the use of access mats, which spread traffic impacts over a larger area; however, no scientific assessments of access mat efficacy have been conducted. Our objectives were to assess the potential of access mats to decrease grassland disturbance and promote subsequent grassland recovery, and to contrast changes in the diversity, community structure, and size of soil microbial communities to understand the role of these communities in facilitating MGP recovery. Multiple sites were established within MGP ecosystems at the University of Alberta Mattheis Research Ranch in SE Alberta. Treatments at each site included natural non-disturbed vegetation controls (CON), areas affected by direct traffic (TON), and prairie with access mats placed for 12 weeks with traffic applied (AM). Soil was sampled in July 2015 and 2016 from two sites; soil DNA was extracted and used to target N-cycling genes via qPCR (n=12) and for next-generation sequencing (Illumina Miseq) (n=3) of bacterial, archaeal, and fungal communities. The sizes of targeted N-cycling communities were impacted by soil texture, and in some cases by traffic treatments applied. Nonmetric multidimensional scaling and perMANOVA indicated statistical differences in fungal communities between CON and TON plots and between TON and AM plots. Indicator species analysis was used to identify operational taxonomic units most responsible for community shifts related to traffic disturbances. Results suggest fungal communities are particularly sensitive to direct traffic, which may be mitigated by access mat use, and that changes in N-cycling communities may relate to ecosystem functioning of grasslands recovering after industrial disturbance.

Preferred Platform: Oral Presentation

Student Presenter: N

Nitrogen cycling genes in a long-term land-use converted boreal land in Newfoundland, Canada

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In Newfoundland, Canada, the productivity of agricultural land converted from boreal forest is sustained by additions of significant amounts of mineral and organic fertilizers, and management of pH through addition of alkaline amendments. The efficiency of fertilization is determined by the efficiency of the soil microbial community. This study examined the impacts of long-term management (≈ 70 years) on the soil (N)itrogen-cycling potential and gene profile in a potato-wheat farm field in Cormack, Newfoundland. The distribution of ammonia oxidation (Cren-, Arch-, bacterial- amoA) and denitrification (narG, napA, nirK, nirS, nosZ1) genes were evaluated on transects across the field's boundaries. Gradient sample points were outside (-3m, -1m) and inside (1m, 3m, 5m) the farmed plot. Triplicate soil samples were collected at 0-10 and 10-20 cm depths along gradients at four sites. Results are contextualized by soil pH, organic matter, total carbon, available and total phosphorous, total- N, mineralizable-N, and C:N, N:P, and C:P ratios. Sampling was carried out at the end of August. N-cycle genes were quantified by digital PCR. Soil physicochemical parameters were measured via standard soil analytical methods. Multidimensional statistics were employed to explore the (a)biotic triggers for the diversity of N-cycle genes, while the most informative models were identified via Akaike's Information Criterion. Diversity of abiotic and biotic parameters were linked to site and gradient location. For 0-10 cm, models confirmed varying levels of correlation between the abundance of each gene, the spatial variables, and abundance of other genes. For 10-20 cm, the associations between genes were more pronounced, with a lower significance attached to spatial variables. Thus, management effects are less pronounced for the deeper soil layer. These results suggest that management affects, as well as a relationship between, the abundance profiles of soil denitrifiers and nitrifiers.

Preferred Platform: Oral Presentation

Student Presenter: Y

Nitrous Oxide Emissions with Organic Crop Production Depends on Fall Soil Moisture

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Agriculture is the major anthropogenic contributor to global nitrous oxide (N₂O) emissions. Many studies have examined soil N₂O emissions from synthetic nitrogen (N) fertilizer additions, however, in organic production where plough-down of forage legumes are often used as a nitrogen source, emissions are as not well understood. In the current study, the Glenlea Long-Term Organic Crop Rotation Study near Winnipeg, Manitoba, was used to compare N₂O emissions of a conventional annual grain and an organic mixed forage-grain system. Static-vented chambers were used to determine N₂O emissions for the 2014 and 2015 crop years; from spring planting to freeze-up and again during thaw following spring. Treatment plots monitored were spring wheat and two-cut harvest with late-summer or early-fall plough-down alfalfa for the organic system, and spring wheat and soybean for the conventional system were monitored in each study year. The organically produced alfalfa received composted dairy manure manure in 2014 and only conventional wheat crops received fertilizer N as urea. Cumulative emissions (g N₂O-N ha⁻¹) with organic wheat were half that of conventional management. Cumulative emissions for the legume crops in the 2014 crop year were very low (200 g N ha⁻¹) and not affected by management. No or very low emissions occurred shortly after plough-downs in 2014 and 2015, and during thaw in 2015. However, fall soil moisture was higher in 2015 resulting in nitrate accumulation from alfalfa plough-down and high subsequent N₂O emissions during spring thaw in 2016. Over both study years, management did not affect yield-scaled emissions for wheat unless thaw emissions from ploughed down alfalfa were included. In conclusion, the benefit of organic cropping on N₂O emissions was dependent upon the soil moisture level in fall that preceded the spring thaw period.

Preferred Platform: Oral Presentation

Student Presenter: N

Investigating the relationship between soil microbial communities and nitrogen cycling and crop nitrogen uptake among diverse canola lines

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Brassica napus L. (canola) is a dominant oilseed crop in western Canada; however, crop production is nitrogen (N) intensive and N fertilizer is the highest input cost to canola growers. Thus, improving N acquisition and utilization has become an important goal in canola production. The objectives of this study were to characterize microbial community composition, extracellular enzyme activities, and soil N processes, and to test relationships between these factors to N uptake among diverse *B. napus* lines over time. Sixteen diverse lines of *B. napus* were grown on a Dark Brown Chernozem soil in Saskatchewan, Canada. Root-associated soils were collected from each line weekly from the rosette stage to maturity, and aboveground plant material was harvested and analyzed for N content. Both nitrate-N and ammonium-N decreased over the growing season, with significant differences between lines for nitrate, but not for ammonium. Interestingly, both nitrate-N and ammonium-N peaked around the flowering- pod filling stages, but decreased again towards plant maturity. Aboveground plant N and seed N were significantly different across the varying canola lines. Additionally, urease and B-1,4-N-actylglucosaminidase activities were measured to assess N cycling activity, while rhizosphere microbial community composition was determined through amplicon sequencing of bacterial 16S rRNA genes. Redundancy analyses will be used to test relationships between plant N uptake and soil microbial N processes for these diverse canola lines. By characterizing N uptake and soil N processes, this research will advance efforts to develop *B. napus* lines capable of efficiently utilizing N resources.

Preferred Platform: Oral Presentation

Student Presenter: Y

Winter-hardy legumes: important non-fertilizer N sources for corn in soybean-wheat-corn rotation

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Soybean-winter_wheat-corn rotation is common for grain growers in humid southern Canada. There are two fallow periods in this rotation, one from wheat harvest (late July) to the following corn planting (May in next year). Fallow bears a high risk for nutrients leaching from the crop root zone into the water systems, eventually into the Great Lakes in the region. We aim to include a legume season into rotation after wheat harvest and to determine the amounts of nitrogen(N) in cover crops, the reduction of residual soil mineral N (RSN) before dominant overwinter leaching season, and N credit to the following crop corn. The experiment was conducted on a sandy loam soil at Harrow, Ontario, Canada (42°1'38"N, 82°54'33"W) using a randomized complete block design with four replications. Annual average temperature and annual average precipitation are 9.2 °C and 825 mm, respectively. Winter-hardy legumes used in this study were crimson clover(CC), hairy vetch(HV), and red clover(RC). Two non-cover crop controls, a conventional control (CKC, 170 kg N ha⁻¹) and a zero control (CKO, 0 kg N ha⁻¹), were also included. This study reports the data collection from 2013-2017. CC, HV and RC are viable post winter wheat cover crops in southwestern Ontario as they establish very well and are winter-hardy. Before freeze-up (early Dec), legume cover crops scavenged 150 kg N ha⁻¹ more N (biomass N) than no cover crop controls, and they reduced RSN by 50 kg N ha⁻¹ relative to the conventional control. Legumes refreshed and scavenged more N (250-300 kg N ha⁻¹) in following spring, and the legumes were plowed down in early May as a sole N source for corn in the legume treatments. The corn yields were 14 Mg ha⁻¹ for the CKC and only 6 Mg ha⁻¹ for the CKO; in comparison, the corn yields were 12, 13 and 13 Mg ha⁻¹ for CC, HV, and RC treatments, respectively. Winter-hardy legumes could be important non-fertilizer N sources for corn in soybean-winter wheat-corn rotation.

Preferred Platform: Poster Presentation

Student Presenter: N

CSSS_07: Delivering healthy soils and climate resilience through policy and program delivery

Conveners: Adam Gillespie¹

Co-chairs: TBD

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Temporal C and N soil attributes as influenced by medium-term cover crop and winter wheat straw removal

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Cover crop (CC) and cereal straw removal are known to influence soil quality, however, little consideration is given to their impact on the temporal variability. Therefore, this study was conducted to evaluate (a) the impact of management on the temporal dynamics of twelve soil quality indicators, and (b) to select a minimum data set (MDS) of temporal C and N indicators from two medium-term CC experiments at Ridgetown, Ontario, established in 2007 and 2008. The CC treatments (7 yr) were no-cover crop control (no-CC), oat, oilseed radish (OSR), cereal rye, a mixture of OSR and rye (OSR+Rye); straw treatments (3 yr) were straw retained (+S) and removed (-S); main crops were winter wheat followed by tomato in 2015 and 2016. Surface (15 cm) soil was sampled before tillage, at tillage, and 5 times during the tomato season. Soil organic C was greater with a cover crop than without, reflecting the medium-term impact of CC on soil quality. There were few significant effects in 2015, but in 2016 there were many two-way interactions. In both years, sampling at tillage had the lowest values for all attributes. In 2016, when significant (10 of 12 indicators), OSR, OSR+Rye and rye had greater concentrations than no-CC but response was often influenced by sampling time (7 of 12). The only three-way interactions were with water stable aggregates in 2015 and Solvita labile amino N (SLAN) in 2016. Using principal component analysis (eigenvalues 0.3), parameters selected for MDS were water extractable organic C and N (WEOC, WEON), Haney soil health test score, Solvita, inorganic N, and microbial biomass C, suggesting higher sensitivity of these attributes over the growing season. Our results provide valuable information on the selection of MDS for developing soil quality indices, and highlights the medium-term as well as temporal influences of CC on C and N soil attributes.

Preferred Platform: Oral Presentation

Student Presenter: y

Developing a soil health index for Atlantic Canada

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The present state of soil health in Atlantic Canada is relatively unknown, although recent reports and evidence indicate it is on the decline. The Atlantic Soil Health Lab was created through the AAFC's Agricultural Greenhouse Gas Program to collaborate with academics, government, and the agricultural community to establish baseline data on soil health in Atlantic Canada. In 2016 and 2017 we have sampled farms and research plots from Nova Scotia and PEI from a variety of agricultural industries with the help of the Nova Scotia provincial extension organization, Perennia, and the PEI Department of Agriculture and Fisheries, for a total of 1320 individual soil samples. We have been testing a suite of laboratory measures and adapting them for this region, focusing on soil carbon, soil nitrogen supply, and soil health starting with the Cornell Soil Health Test. Of the 278 farm samples collected in NS in 2016 the average organic matter (OM) was 3%, with forage fields (n=5) having the highest organic matter at 4.7% and vegetable fields (n=34) having the lowest at 2.3%. OM on PEI also averaged 3% but has not yet been examined by sector. Aggregate stability was measured using a rainfall simulator and again in NS the forage fields had the highest percentage of stable aggregates (67%) while vegetable fields had the lowest percentage (40%). There was widespread excess phosphorus in NS, with the average P2O5 for all 2016 fields at 1092 kg/ha while the provincial guidelines put anything at or above 617 kg/ha as excessive. Excess P was less of an issue on PEI, with average P2O5 in 2016 at only 394 kg/ha. Completed data from 2017 sampling will be included in the presentation as well. Progress on developing a soil health index for Atlantic Canada will be discussed along with implications for soil health in this region.

Preferred Platform: Oral Presentation

Student Presenter: Y

Implementing Ontario's Agricultural Soil Health and Conservation Strategy

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Agricultural soils have challenges of climate change, changing farm practices and declining soil organic matter. A Soil Health and Conservation Strategy was developed collaboratively by farm groups, conservation agencies, academia and government. Four theme areas include: Soil Management; Soil Information and Mapping; Soil Monitoring and Modelling; and Soil Knowledge and Innovation. The soil management theme includes actions to support soil Best Management Practices adoption through development, education and incentives. Soil data and mapping actions seeks to modernize soil maps and inventory and build soil databases. Soil evaluation and monitoring actions seek to track soil health at different scales. Soil knowledge and innovation actions address research, diversifying learning approaches, peer-to-peer learning, and post-secondary, elementary and secondary education. Developing an implementation plan and collaborative approach for implementation are next steps.

Preferred Platform: Oral Presentation

Student Presenter: N

What Will it Take to Reduce N₂O Emissions from Manitoba Field Crops to Meet Short-term Emission Reduction Targets?

Mario Tenuta

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Within the next decade, greenhouse gas reductions of 30% from agriculture need to be realized if developing countries are to hope to meet international obligations. This presentation reviews results of studies conducted by the University of Manitoba Soil Ecology Lab since 2004 into 4R Nutrient Stewardship practices that hold promise in achieving required nitrous oxide (N₂O) reductions from cropped soils in Manitoba, Canada. The studies emphasized component 4R practices, with 9 studies for Right Source, 5 for Right Rate, 3 for Right Placement and 3 for Right Timing. Of the practices examined, cropping with N fixing leguminous crops reduced emissions the most. Lowering ammoniacal N additions and increased depth of subsurface placement of N were second most effective in reducing emissions. Application of N fertilizers late in fall prior to winter soil freeze-up surprisingly had lower emissions than spring fertilizer addition. Lastly, enhanced efficiency fertilizers applied to wet soils reduced emissions. Subsurface banding of N fertilizers tended to decrease emissions but less so than the other practices previously mentioned. The potential of 4R Nutrient Stewardship practices meeting short-term nitrous oxide emissions reductions from cropped soils will be summarized.

Preferred Platform: Oral Presentation

Student Presenter: N

**Best Management Practices for Greenhouse Gas Mitigation in Ontario Cropland –
Synthesis of Knowledge**

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A synthesis of knowledge study was undertaken to inform OMAFRA policy makers on GHG mitigation potential with best management practices (BMP) for Ontario Croplands. A literature review was conducted on N₂O (direct and indirect) and CO₂ emissions and on soil organic carbon (SOC) storage for practices including: fertilization rate, timing and method of fertilizer application, fertilizer types and the use of inhibitors, use of reduced tillage, use of cover crops and diversification, planting of biomass crops, and afforestation. The review focused on the literature that is relevant to Ontario's climate and production systems. We calculated a baseline of N₂O emissions from crops based on the 2016 census to be ca. 2.27 kg N₂O-N ha⁻¹ (1.06 Mg CO₂e ha⁻¹) in Ontario. The ranges of N₂O reduction from specific BMPs were wide. Because of that, the most likely mitigation potential was from BMPs that showed least variability (or that applied to a broader set of conditions). Matching of N rate to crop demand, use of nitrification inhibitors or double inhibitors (urease + nitrification), reduced tillage (zone tillage on corn), were amongst the practices that were shown to reduce N₂O emission compared to the conventional alternative. Use of cover crops and biomass crops and afforestation were also found to mitigate GHG by increasing SOC storage with some effect on GHG reductions. Some of the BMPs that were expected to be effective in GHG reduction were not supported by consistent literature findings. These included side-dress N application, split-N application, manure use to replace mineral N fertilizer, and biochar use. Meta-regression analysis showed that tillage, time and source of N application and soil textural group are factors that affect fertilizer induced N₂O emission (FIE).

Preferred Platform: Oral Presentation

Student Presenter: N

Application of a “soil-fingerprinting” framework in a medium-term cover crop experiment in southwestern Ontario

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Measuring soil health is difficult as it represents the integration of soil physical, chemical and biological characteristics at a given time under specific conditions. Therefore, a “soil fingerprinting framework” has been developed based on soil taxonomic principles and consists of symbols and syntax to describe and track changes in dynamic soil properties. Soil characteristics are depicted in a “fingerprint code”, which is specific to the sample at the time it was sampled. Soil properties recorded in the current version of the framework are described in different levels ranging from 1 to 5. Level 1 includes soil processes and environmental context, level 2 soil structure and bulk density, level 3 organic C, level 4 pH and electrical conductivity, and level 5 soil surface conditions, land use and slope. Although the framework has proven valuable in Canada, and Germany, it has never been evaluated in a cover crop (CC) based cropping system in Canada. Therefore, this study was conducted using two medium-term CC experiments initiated in 2007 and 2008 with the objectives of developing fingerprint codes. There were four CCs and a no cover crop control and winter wheat straw was retained or removed. Soil was fingerprinted in 2015 and 2016 according to Agriculture and Agri-Food Canada guidelines. Soil structure was found to vary between sub-angular blocky and granular for all treatments at both sites. Soil properties (0-15 cm depth) ranging from level 2 to level 4 were found to differentiate between the CC and straw treatments, suggesting the role of these properties in influencing soil quality in the medium-term. Our results highlight (a) value of the framework in describing differences in the dynamic soil properties among different management practices, (b) suggests incorporation of additional endpoints to improve its applicability, and (c) indicates the adaptability of the framework in evaluating temporal and spatial variation in the soil quality attributes.

Preferred Platform: Poster Presentation

Student Presenter: Y

Using the Solvita® [CO₂] 2-Burst test as a biological indicator of soil fertility across various cropping systems in Ontario

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Soil physical and chemical properties have historically been the focus when assessing soil fertility from an agricultural context. However, the biological components of soil have been increasingly recognized as an important aspect when assessing soil fertility. Soil microbial biomass contributes to nutrient cycling and the mineralization and immobilization of soil N, making soil microbial activity a useful proxy to estimate soil fertility. The Solvita® CO₂-Burst test measures the amount of CO₂ released by soil microbes over a 24 hour period, and can be used as a biological indicator of soil fertility. It is unknown whether the Solvita® CO₂-Burst could be utilized to accurately indicate soil fertility across diverse cropping systems in Ontario. Due to the low cost and wide availability of the Solvita® CO₂-Burst test, the test could be utilized by farmers as a biological indicator of soil fertility. Long-term experiments were established in Elora, Bornholm, Ridgetown, and Lucan. Each experimental trial consisted of crops in a corn, soybean and winter wheat rotation. Samples from the first 0-15 cm of the soil were taken in either the spring or the fall, and analyzed using the Solvita® CO₂-Burst test. This experiment was completed to determine i) if crop type impacts Solvita® CO₂-Burst test results ii) if the timing that the soil sample was taken impacts results, and iii) whether test results are consistent across locations. Preliminary results showed that CO₂-Burst values were consistent regardless of the crop in rotation at Ridgetown and Bornholm. In addition, the timing of the sampling (spring or fall) did not impact CO₂-Burst values at Ridgetown. However, statistically higher CO₂-Burst values were observed in the spring than in the fall at Bornholm. Next steps will be to continue to analyze the remaining sites, and determine whether crop type and sample timing impacts results, as well as whether results remain consistent between sites.

Preferred Platform: Poster Presentation

Student Presenter: N

Evaluating Two Commercially-Available Soil Health Indicators Using Two Ontario Long-term Tillage System and Crop Rotation Experiments

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Farmers seeking knowledge on soil health are purchasing commercial tests such as Solvita CO₂ burst respiration and SLAN (Solvita labile amino N). However, the efficacy of these tests to detect soil health differences among common field crop practices has not been evaluated in Ontario. Therefore, soil samples (surface 15 cm) were collected in June from two long-term tillage system (no-till/zone tillage (NT) vs. fall, full inversion (CT)) and crop rotation (corn (C), soybean (S), winter wheat (W), small grain cereal undersown red clover (rc), alfalfa(A)) experiments at Elora (silty loam, Gleyed Melanic Brunisol) and Ridgetown (clay loam, Orthic Humic Gleysol). Soil was sieved (2 mm) and dried (50°C) prior to separate 24 hr incubations of 40 g soil with 25 mL dH₂O with Solvita colourmetric paddle and 4 g with 10 mL of 2 N NaOH with SLAN paddle. Evolved CO₂-C and NH₃-N, respectively, were quantified with a digital reader where greater concentrations indicate better soil health. At both sites, the phase of crop rotation did not influence concentrations ($P > 0.05$), perhaps suggesting that the tests were detecting long-term rather than seasonal, crop-specific effects. At both sites, evolved CO₂-C and NH₃-N were 6.7% to 33% greater in NT than CT systems. At Elora, the greatest values of both Solvita and SLAN indicators were in continuous A (114 mg CO₂-C kg⁻¹ and 151 mg NH₃-N kg⁻¹, respectively) and the lowest in C-S rotation (49.4 and 103 mg kg⁻¹, respectively). At both sites, rotations with rc, W, or other small grain cereals had or tended to have greater values than C-S and continuous S. The observed tillage system and crop rotation results with Solvita and SLAN were consistent with previous research at these sites on soil health (Cornell soil health test and soil organic C) in surface soil and crop productivity and resiliency. Thus, this research suggests that both commercial tests may be useful indicators of soil health in Ontario.

Preferred Platform: Poster Presentation

Student Presenter: n

CSSS_09: Modelling and mapping of the terrestrial environment

Conveners: Asim Biswas¹, Adam Gillespie², Daniel Saurette³, Brandon Heung⁴, Jacklyn Cockburn⁵

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Predictive digital soil mapping: outcomes of optimizing a field program in the Ottawa area

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Predictive digital soil mapping is a promising mapping approach which seeks to leverage remotely sensed phenomena and computational modelling to predict soil properties. This approach should, by definition, reduce the amount of fieldwork and associated costs required to generate a soil map. Nevertheless, computational modelling approaches are based in concepts of machine learning which require some site data as inputs to the model. The challenge then centres on developing and deploying an efficient field sampling program that fulfills the data requirements of the modelling approach. This presentation details a sampling process based on the conditioned latin hypercube approach which optimizes the number of samples required to cover a particular landscape. Then, we highlight certain challenges with field deployment of this landscape-based sampling design. Finally, we show preliminary predicted soil property surfaces (texture, carbon, pH) generated from these sample points in a pilot area in the western part of the City of Ottawa.

Preferred Platform: Oral Presentation

Student Presenter: N

Supporting Enhanced Forest Inventories using High-Resolution Digital Soil Mapping Techniques

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The soil is essential to forested ecosystems as it provides a medium for plant growth and is a critical component for the cycling of water, nutrients, and carbon. To effectively manage the productivity of forests and support future land-use decisions at the site level, high-resolution and accurate spatial soil information is required. The objective of this study was to assess the efficacy of airborne-LiDAR data and field observations for the development of digital soil mapping (DSM) products using machine-learning techniques. Here, soil textural classes, soil moisture regime, and soil mottling depths were mapped for the Hearst forest (northern Ontario) at a 10 m spatial resolution. To develop the dataset used to train the machine-learning model, approximately 10,000 georeferenced soil observations were acquired from the Forest Ecosystem and Classification dataset. The point data was then spatially-intersected with a suite of environmental data layers representing topography, hydrology, surficial geology, and bedrock geology. The training dataset was submitted into a Random Forest (RF) classifier, where the soil-environmental relationships were quantified. The fitted models were then used to predict the spatial distribution of the target soil attributes. To validate the model outputs, the RF algorithm was trained using a random selection of 70% of the training data and the remaining 30% was used to validate the predictions. The fitted RF models were used to produce DSMs for the Hearst forest, where 10 moisture regime classes, 7 soil mottling depth classes, and 42 soil textural classes were predicted with associated accuracy rates of 77.3%, 72.5%, and 74.3%, respectively. Although the results are still preliminary, they are very promising. Future work will assess the transferability of these DSM techniques on other managed forests in Canada.

Preferred Platform: Oral Presentation

Student Presenter: No

Predictive digital soil mapping of wetland soils in the Prairie Pothole Region of Canada

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Agricultural intensification and wetland drainage across the Prairie Pothole Region has resulted in nutrient loading of the watersheds that ultimately contribute to Lake Winnipeg, resulting in its eutrophication. Wetlands of this region provide numerous ecosystem services including reducing nutrient mobility in a watershed. Certain wetland soils (those enriched with calcium carbonates) have been found to be more effective at retaining phosphorus. By determining the spatial distribution of these wetland soils, upscaled estimates of phosphorus retention in Prairie Pothole Region wetlands could be established. It would also allow for the prioritization of conservation and restoration efforts to preserve and encourage this ecosystem service. Soil sampling was conducted in fall 2015 and 2016 at three sites that spanned the brown, dark brown, and black soil zones of the prairies. Several machine-learning techniques were tested to model the spatial distributions of wetland soil types. The models incorporated landscape variables derived from high-resolution LiDAR-based digital elevation models. A few knowledge-based landscape variables were developed specifically to reflect the unique characteristics of the prairie pothole region's morphometry. The soils were mapped with relative success; the models achieved upwards of 60 % accuracy in their predictions on independent validation sets.

Preferred Platform: Oral Presentation

Student Presenter: Y

Digital soil mapping of Middlesex county using legacy soil data

Sarah Lepp, Danielle Saurette, Rebecca-Jo Vastergaard, Parisa Pirouzan, Adam Gillespie, Prasad Daggupati, Asim Biswas

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The demand for up-to-date and relevant soil information need has been expressed by the modelling community, land managers, policy developers and decision makers. While traditional soil maps typically show only general distribution accompanied by the soil survey report, digital soil maps are richer in context with greater spatial detail. Soil data is critical for digital soil mapping but collection of soil samples at large areas (e.g. Middlesex) is challenging and often restricts the mapping activity. On contrary, legacy soil data shows promise in developing soil maps. The objective of this project was to develop digital maps of different soil properties of Middlesex county using legacy soil data. About 1600 locations within the county was studied and pedological information was collected during the soil survey in 1980's by OMAFRA. Among these, soil samples from about 1200 locations were analyzed in laboratory for various soil properties. Geographic locations for these samples was confirmed using supporting information. Additionally, as no information on sampling design was available, a detailed analysis on spatial representation of these samples was carried out following complete spatial randomness test. Overall qualified samples were then divided into two groups; calibration (70%) and validation (30%) and regression kriging mapping model was used to develop digital soil maps at two spatial resolutions; 100 m and 250 m. Environmental covariates (e.g. DEM, terrain attributes, soil maps, geology, satellite images, environment data, and others) were collected from various available sources, processed in 2 resolutions and used to develop predictive model. Validation of the maps was carried out using cross-validation and the validation set. Uncertainty maps of prediction were prepared for each soil property. While this study provides a detailed soil maps of the county, the methodological framework can be used to develop maps for other parts of the province.

Preferred Platform: Oral Presentation

Student Presenter: Y

Stream Corridor Mapping using UAS and LiDAR Technology: Implications for Bank Erosion Modelling

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Bank erosion can be the primary nonpoint source polluter of waterways, and combating the damage from elevated levels of suspended sediments in waterways is costly. Despite the ecological and economic implications of bank erosion, the amount of sediments and nutrients contributed from bank erosion is poorly understood. Novel unmanned aerial system, LiDAR, and software algorithms (e.g., structure from motion) have enabled the recreation of detailed three dimensional virtual representations of our terrestrial environment. The capacity of these technologies for mapping out stream corridors is not well understood, especially across large spatial extents. As a step toward understanding the potential of these technologies for stream-corridor mapping, a series of stream corridors in southwestern Ontario were mapped using a terrestrial laser scanner, unmanned aerial system (via sfm-photogrammetry), and traditional manual mapping. The spatial accuracy and temporal efficacy of each technique was evaluated using cloud-to-cloud distances (i.e. bank heights), bank slopes, and wetted widths. In addition to presenting results, the applicability of each technique is evaluated for informing bank erosion models and calculating volumetric bank erosion rates. We conclude by discussing lessons learned while conducting UAS and TLS data collection and present best management practices in using sfm-photogrammetry software.

Preferred Platform: Oral Presentation

Student Presenter: Y

Predictive Digital Soil Mapping: Keene Pilot Area, Peterborough, Ontario

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Predictive digital soil mapping (PDSM) is a rapidly evolving sub-discipline of soil science which is garnering more and more attention across Canada. The Ontario Ministry of Agriculture, Food and Rural Affairs is working to develop PSDM techniques to allow for updates to soil maps across the province using pilot areas nested within larger county-wide soil surveys. One such project is the Keene PDSM pilot area in Peterborough County, ON, a 10,000 hectare study area that was the focus of field investigations in 2016-17. The PDSM techniques being developed rely on coupling high-resolution elevation data, derivatives created from the elevation data, and other environmental data such as surficial geology and radiometric data, used to represent soil forming factors, with field and analytical data to create predictive models that allow for mapping of soil properties across a study area. Approximately 100 soil inspections were completed in 2016-17 with detailed soil sampling by horizon. Samples were submitted for various physical and chemical analyses. Using the caret package in R, various models, including Cubist and Random Forest, were examined to determine their suitability for modelling various continuous soil properties and categorical soil classes in the Keene pilot area. Here we examine models and maps for continuous properties (sand, silt, clay, organic carbon, pH) and maps of soil attributes that can be derived from the soil property maps such as available water holding capacity.

Preferred Platform: Oral Presentation

Student Presenter: N

Spatio-temporal variations in arctic tundra snow depth and water equivalent over the duration of the spring snowmelt using an Unmanned Aerial System

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Snow water equivalent (SWE) plays an important role in northern environments and can be cited as the most important hydrological variable for Arctic systems. However, documenting snow distribution in tundra environments has proven difficult and is prone to large errors due to the heterogeneous distribution of SWE is stored in large drifts that accumulate blowing snow over the course of the winter months. This is further complicated by a mis-match between the scales of traditional remote sensing and field observations techniques for measuring snow on the ground. With the onset of the spring snowmelt and the initiation of the spring freshet, the heterogeneous snow distribution across tundra landscapes results in sporadic snowmelt patterns which further impacts the timing and magnitude of the spring freshet. Over the duration of the 2016 spring snowmelt a fixed-wing Unmanned Aerial Systems (UAS) was used in combination with Structure-from-Motion photogrammetry to quantify spatial and temporal variations of snow depth and SWE. Eighteen UAS flights across the spring snowmelt provide high-resolution mapping of the spatial distribution in SWE and snowmelt dates for four land cover types allowing for quantification of snowmelt patterns and streamflow contributing areas. This study allows for the analysis of streamflow contributing areas and for the quantification of the relative importance of various landcover units on controlling the runoff availability for streamflow.

Preferred Platform: Oral Presentation

Student Presenter: Y

Soil families: bridging the gap between soil subgroups and soil series

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Advancements in geospatial data and digital soil mapping have prompted revisions to soil maps in the Province of Ontario and across Canada. Soils in the Province of Ontario were surveyed and mapped over a period of about 80 years. The soil series was used as the primary mapping unit for provincial soil surveys while the higher taxa (i.e., Orders, Great Groups and Subgroups) in the Canadian System of Soil Classification were in development. The soil family category was a later addition intended to group and provide a framework for checking and establishing limits for Soil Series while providing a link between the series and the subgroup levels. Unfortunately the Soil Family category was developed after many series were long established and has not been widely used in Canada. The distribution and areal extent of soil series names has not been applied consistently across the Province of Ontario with duplication and use of soil series names occurring across several ecoregions, different parent materials and sometimes with a wide range of textures. As a result, some series must now be subdivided into sometimes several soil families. Given the hierarchical structure of the Canadian System of Soil Classification, some adjustments to the family taxa for mineral soils are proposed as well as some upcoming changes to definitions for various soil series in Ontario; some with long-standing use in the province.

Preferred Platform: Oral Presentation

Student Presenter: N

Developing Soil Correlation Areas for Ontario

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Soil maps are important tools used in many applications, such as assisting growers, planning development, and supporting government policies and regulations. Since they are used for many decisions that have potentially significant impact, it is important to ensure they are as accurate as possible. Soil correlation areas are used to define limits for where soil names can be used to describe a particular soil series. Using surficial geology, ecological classification and other information, boundaries for these correlation areas will be proposed, and a list of soils series that should be found within each can be determined to avoid geographic sprawl of soil series in Ontario, except where warranted. The soil correlation maps can be used to both update the existing soil maps and help ensure consistency in future surveys.

Preferred Platform: Poster Presentation

Student Presenter: n

Correcting Shadows in Multispectral Images Using LiDAR Intensity

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Aerial near infrared multispectral imaging has been widely used for the mapping and monitoring of vegetation. However, these images are commonly affected by shadows cast by clouds, which complicate the classification of vegetation by altering the response of the vegetation relative to sunlit areas. The objectives of this study are two-fold: first, to identify areas of shadow within the multispectral images and second, to correct the colour values in shadowed areas to match sunlit areas using airborne LiDAR data. In order to quantify how much the LiDAR data improves shadow classification, support vector machine classification was performed using the individual RGB bands of the multispectral image, the multispectral intensity and the LiDAR intensity data as separate inputs. The LiDAR intensity classification performed the best, classifying 125% more areas of shadow than using the RGB bands and 14% more than using the multispectral brightness. The multispectral brightness worked better than the LiDAR intensity for classifying shadows where there was a large contrast between the sunlit and shadow colours (ex. grass covered areas) but worse for areas that were similarly coloured (ex. exposed dirt and pavement). Therefore, it is recommended that a hybrid of the two is used. To achieve our second objective, four colour correction techniques were tested with the corrected images used for improved land cover classification and NDVI map creation. Target application areas include land surveying for pipeline right-of-ways, mine site surveying, wildfire management and free-to-grow surveys.

Preferred Platform: Poster Presentation

Student Presenter: Y

Improving Ontario's Soil Maps: Topographic Updates and Implications for CLI Ratings

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Soil survey in Ontario has a rich history with production of county soil survey maps and reports over a period of over 80 years. In the early 2000s, with the increased access to Geographic Information Systems (GIS), the county soil survey maps were digitized and combined to create a stitched product covering most of southern Ontario and parts of northern Ontario. The ability to combine the data into a single database enabled thorough analysis of the provincial data, and issues and limitations in the data quickly became apparent. One such limitation was the topographic information presented in the database, including slope percent, slope class and slope range. Throughout the years, slope classes have evolved and there exists discrepancies between the soil surveys. In addition, there is a general lack of understanding regarding the approach that was used to assign a slope to a particular soil polygon (most limiting slope, average slope, dominant slope, etc.). Another issue is the tendency for soil surveys to be conducted along concession roads, which allows the surveyor a view of a limited percentage of the agricultural landscape. With the development of Digital Elevation Models, the modern soil surveyor now has access to detailed elevation and slope information for the entire land surface which allows assigning slope classes using a systematic, defensible approach. Current updates are underway for a large number of counties in Ontario. The best available DEMs are sourced for each county. Slope maps are generated from the DEMs and geo-statistical analysis is conducted to determine an appropriate slope class for the soil polygon. Once slope classes are assigned, agricultural capability ratings are adjusted, as required, based on the revised slope class following Ontario's guidelines for classifying prime and marginal land in Ontario.

Preferred Platform: Poster Presentation

Student Presenter: N

Sources of data for DEM creation and their comparison for use with Predictive Digital Soil Mapping (PDSM)

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Predictive Digital Soil Mapping (PDSM) relies heavily on the use of a Digital Elevation Model (DEM) and derivatives created from the DEM to make predictions about soil properties across a landscape. There are numerous data sources and methods that can be used to create a DEM, and each source and method can produce different results, having an influence on any derivatives created from the original DEM. In central Ontario, three different elevation data sets exist, making this an ideal site to compare and contrast different DEM sources. The Ontario South Central Orthophotography Project (SCOOP) DEM, Greater Toronto Area (GTA) DEM, and Light Detection and Ranging (LiDAR) coverage in the vicinity of Peterborough County will be compared to examine the accuracy of each elevation product and methods used to produce each result. An accurate DEM at a fine resolution is necessary to compute elevation derivatives at a precise enough scale to ensure the landscape isn't interpreted too broadly and that important landscape features are not missed, while also ensuring the data is not too precise (e.g. a resolution fine enough to properly capture the slope values on the side of a drumlin, but that omits micro-features such as individual furrows from cultivation). The poster will demonstrate how LiDAR allows the user to create DEMs at different resolutions to suit the scale preferences of a soil mapping/modeling project. While pre-assembled elevation products are readily available, they can only be resampled from the product provided and not recreated from the original elevation points, which is less effective and gives less freedom to the user to apply the data to multiple project scales.

Preferred Platform: Poster Presentation

Student Presenter: N

Spatial interpolation of legacy soil data: Comparing deterministic and geostatistical methods

Rebecca-Jo Vastergaard, Sarah Lepp, Danielle Saurette, Parisa Pirouzan, Perry Taneja, Adam Gillespie, Prasad Daggupati, Asim Biswas

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Spatial interpolation is the procedure of estimating the value of properties at unsampled sites within the area covered by existing observations. The observation that are close together in space are more likely to have similar values than points far apart and is the main rationale behind spatial interpolation. It is an important feature in many geographic information systems and mainly divided into two categories; deterministic and stochastic interpolation. While, there are many methods under each category, a detailed comparison is necessary in identifying best methods for spatial interpolation of legacy soil data, which often suffers from definite sampling design and distribution, and insufficient numbers. The main objective of this study was to compare various deterministic (e.g. inverse distance weighting, global and local polynomial, radial basis function, splines, etc.) and stochastic (e.g. several types of kriging and cokriging, empirical Bayesian kriging, etc.) interpolation methods. About 1200 soil samples with laboratory measurements from Middlesex county was collected from OMAFRA soil survey carried out in late 1980's. Samples were examined for their geolocations and quality checked before use in interpolations. Overall qualified samples were first separated into calibration (70%) and validation (30%) dataset and used to develop interpolated maps of the county using ArcGIS and R programming language. The effectiveness of the interpolations techniques was tested using coefficient of determination and root mean squared error between calibration and validation sets. While the interpolation provides first hand information on the spatial distribution of soil properties, soil mapping based on environmental covariates (e.g. digital soil mapping) should be compared to incorporate pedological knowledge base in quantifying spatial distribution of soil properties.

Preferred Platform: Poster Presentation

Student Presenter: Y

An analysis of legacy gamma-ray spectroscopic datasets for use in predictive digital soil mapping of the City of Ottawa, Ontario

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Renewal of Ontario's agricultural soil maps and information will require both the use of new technologies and examination of existing data to facilitate the mapping. Previous gamma-ray spectrometric (radiometric) surveys have been performed for surficial geology mapping; however, these legacy datasets can also provide valuable information on the spatial variability of some soil properties, particularly clay content. This geospatial soil texture data can be used as an environmental co-variate to aid in predictive digital soil mapping efforts. The City of Ottawa is the pilot study area for the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) mapping renewal project. Three legacy radiometric surveys exist which cover incomplete portions of the City boundary. The radiometric surveys were flown with a fixed-wing aircraft at flight line spacings of 5, 1 and 0.5 kilometers. Statistical analysis will be performed to compare clay content as mapped by gamma-ray spectrometry at three different scales, and clay content obtained through laboratory analysis of soil samples. The aim of this project is to determine the optimal radiometric survey scale that best describes clay content in the field. This information will be valuable for prospective radiometric survey acquisition as well as further predictive digital soil mapping for the City of Ottawa.

Preferred Platform: Poster Presentation

Student Presenter: N

Using DSM techniques to model a small drainage area in southwestern Ontario

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Soil maps are spatial depictions of soil characteristics and are widely used to implement best management practices, support development plans, enforce regulations, and many other applications. Given that decisions made by the public or governing agencies using these maps can have significant legal, environmental, and economical ramifications, it is critical that the soil maps available are accurate reflections of the environments they represent. The soil maps currently used by Ontarians were established between the 1920s to the late 1990s. Surveys were completed by different surveyors, in many cases with outdated technology, and at different mapping scales. When digitized, differences in accuracy between and within soil surveys became more apparent. Based on this observation and in response to the need for more accurate soil information, the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), began working towards applying innovative digital soil mapping (DSM) techniques to update the soil maps of Ontario. Our study explores the application of DSM on a small-scale study area. In 2016, 19 sites were sampled in an agricultural field within Middlesex County in southwestern Ontario. At each location, site and horizon descriptions were recorded and each horizon was sampled. Samples were analyzed for particle size and carbon. Sample data was modeled in R using environmental covariate rasters to discern which variables best predict the soil characteristic of interest. Models were then applied to the entire covariate raster to make accurate predictions for the site. Our study aims to understand how sample size affects model selection and how models compare with larger scale modelling of same variable. Given that OMAFRA aims to provide updated soil maps for the agricultural regions of the province, it is paramount that we understand how maps at different scales of the same area will differ and how this affects interpretations for Ontarians.

Preferred Platform: Poster Presentation

Student Presenter: N

Efficient Measurement of Topographic Roughness Using Surface Normal Vectors

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Digital elevation models (DEMs) are frequently used to derive information about topographic roughness. DEM-derived roughness metrics characterize terrain ruggedness and complexity. These metrics have been widely applied in geoscience and environmental research previously. For example, roughness maps have been used to delineate large-scale geological units on planetary bodies, for the study of slope failures, and to model fire behaviour. This study describes the development and geomorphometric application of a measure of surface complexity that has previously only been applied in the field of surface metrology. This physically intuitive measure of surface roughness uses the angular deviation between a surface's normal vector field and the normals of a corresponding ideal (i.e. smoothed) surface to quantify surface complexity. Specifically, roughness is defined in this study as the neighbourhood-averaged difference in the normal vectors of the original DEM and a smoothed DEM surface. The efficiency of the DEM smoothing operation was improved by using a highly efficient integral-image approach that offers constant-time performance scaling with filter size. This characteristic enabled mapping of roughness patterns at very large spatial scales. Case studies of regional-scale roughness mapping are used to demonstrate the application of this metric.

Platform: Poster Presentation

Student Presenter: Yes

CSSS_10: Geosensing

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Comparison of uncertainty in land cover classification processing workflows using airborne LiDAR data

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This study compares different processing workflows for classification of land cover from single wavelength, discrete return LiDAR data collected over a near-pristine landscape at the Queen's University Biological Station in Eastern Ontario. We focus on addressing the need for more comprehensive analyses of the impacts of various modeling decisions on uncertainty in land cover models derived from airborne LiDAR data. We compared the overall accuracy, class-specific precision and recall, and configuration of six land cover models. Three data modeling options are tested: the organization of data into tile or flight-strips, classification of LiDAR-derived raster surfaces or of the point cloud directly, and the use of pixel- or object-based image analysis techniques. Results confirm that object-based image analysis outperforms pixel-based image analysis, with accuracies of 92%. Analysis of data organized into tiles had consistently higher accuracies than when organized into flight-strips. Finally, we found that direct classification of the point cloud achieved similar accuracies as models generated with LiDAR-derived raster surfaces. Model uncertainty is commonly presented as absolute, without addressing the spatial distribution of error within the model. While the uncertainty of two models could be similar, the configuration of landscape features in the models may be quite dissimilar. This is incredibly relevant for some applications, including those that model the distribution and dispersal of species through a landscape. For instance, if misclassifications affect the continuity of a putative barrier to dispersal, such as a road, this could have significant impacts on downstream analyses of the correlation between species' dispersal and landscape. Accurate and robust models of land cover are therefore crucial for a wide range of applications including land use monitoring, landscape ecology, and landscape genetics.

Preferred Platform: Oral Presentation

Student Presenter: Y

A Comparative Analysis of Estimated Soil Moisture from SAR Imagery and Land Surface Modeling

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Soil moisture is a key variable in the Earth system, controlling the exchange of water and energy between the land and atmosphere. Thus, understanding its spatiotemporal distribution and variability is of high importance. Soil moisture variability is a function of rates of evaporation and precipitation. Environment and Climate Change Canada (ECCC) has developed a new land-surface parametrization, the Soil, Vegetation, and Snow (SVS) scheme. The new SVS land surface scheme features more sophisticated parameterizations of hydrological processes, including the soil water transport through the soil. It has been shown to provide more accurate simulations of the temporal and spatial distribution of soil moisture, when compared to the current operational ISBA (Interaction between Soil, Biosphere, and Atmosphere) scheme. Simulation of high-resolution soil moisture at the field scale remains a challenge. In this study, we reproduce soil moisture maps at a spatial resolution of 100 m by running the SVS land surface scheme over a test region located in Manitoba, Canada. Hourly high resolution soil moisture maps were produced between May and November 2015. Soil moisture values using the SVS land surface scheme are compared with estimated soil moisture values for four different dates using a hybrid retrieval algorithm which was developed at Agriculture and Agri-Food Canada (AAFC) for soil moisture estimation using RADARSAT-2 Synthetic Aperture Radar (SAR) imagery. Statistical analysis of the results showed promising performance of the new SVS land surface scheme for reproducing soil moisture values at high resolution scale.

Preferred Platform: Oral Presentation

Student Presenter: N

Distinguish the capillary fringe reflection in a ground penetrating radar profile for precise water table depth estimation

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High-resolution subsurface images of ground penetrating radar (GPR) can be used to estimate water table depth (WTD). The accuracy of the WTD estimations primarily depends on the average radar velocity from the surface to the groundwater table (GWT). The velocity should be defined by the user during data processing within a range from 0.060 m/ns (wet) to 0.150 m/ns (dry) in most soils and sand. On the other hand, accurate detection of the WTD in a GPR radargram is often difficult due to the interference from the capillary fringe. In such a situation, the prominent and early reflection could come from the capillary fringe, but not from the actual GWT. The objectives of this study were to monitor the fluctuation of GWT using GPR in a managed agricultural field throughout a growing season and to evaluate the accuracy of the WTD estimation. The study was conducted in a shallow sandy aquifer in western Newfoundland. In total, 15 GPR surveys were carried out along the same transect (30-42 m long) using 100 and 250 MHz center frequency antennas of PulseEKKO Pro GPR system. A water level sensor was installed in a shallow borehole and a Decagon Em50 data logger was used to record the real-time TWD. The average radar velocities of the soil profile under wet, median and dry conditions were assumed to be 0.090, 0.105, 0.120 m/ns, respectively. We observed in GPR radiograms that the groundwater reflections near the borehole were free from the capillary fringe, and represented the correct WTD. Thus, the observed height of capillary fringe was used to correct the GPR measured WTD. Corrected GPR based WTD is highly correlated ($r=0.987$ and 0.948 for 100 MHz and 250 MHz, respectively; $p=0.000$ at $\alpha=0.05$) with actual WTD. The RMSE values of GPR estimated WTD are ± 0.04 m (100 MHz) and ± 0.08 m (250 MHz) and the accuracy could be further enhanced if exact radar velocities can be used.

Preferred Platform: Oral Presentation

Student Presenter: Y

Using satellite remote sensing to quantify soil cover in the Lake Erie basin

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There is particular interest in the management of agricultural land in the Lake Erie basin during the non-growing season as this is when most of the non-point source nutrient run-off and loading to the lake occur. Both crop residue (dead) and cover/winter crop (living) soil cover are considered beneficial for facilitating water infiltration and reducing soil erosion and nutrient loss. Remote sensing is a valuable tool to assess and map crop residue cover and cover crops in southwestern Ontario. The objective of this study is to evaluate the performance of linear spectral unmixing for estimating, and on-going monitoring, of soil cover in the non-growing season (November-May) over large areas such the Lake Erie basin using multi-temporal satellite imagery. Soil cover ground measurements and multispectral Landsat-8 imagery were acquired over two areas over the non-growing season for three years (2013-2014, 2014-2015, and 2015-2016). Vertical soil cover photos were collected from up to 40 residue and 30 cover crop fields for each area pass when harvest, cloud, and snow conditions permitted. Images and data were reviewed and compiled to represent a complete coverage of the basin for three time periods (post-harvest, pre-planting and post-planting). Preliminary results have shown that overall spectral unmixing of satellite imagery is well suited for estimating and monitoring soil cover in the non-growing season. For instance, the Elgin 2015-2016 pre-planting season corn/soybean residue and green cover fraction derived from linear spectral unmixing were highly correlated with the field measured data (R^2 of 0.75, 0.93, and 0.83, respectively). Results from this study could be used to support performance metrics for Lake Erie phosphorus reduction plans and as input for sustainability indicators that require knowledge about non-growing season land management over a large area.

Preferred Platform: Oral Presentation

Student Presenter: N

Comparison of multi-coil and multi-frequency electromagnetic induction for soil moisture content prediction in shallow soils

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Rapid soil moisture content (SMC) prediction by electromagnetic induction (EMI) is preferable over other geophysical methods for large scale field applications. EMI sensor measures soil apparent electrical conductivity (ECa) as a proxy of subsoil properties. Spatiotemporal distribution of ECa can be related to the variability of SMC across the field. A field experiment was conducted on a silage corn field (8 x 42 m²) at Pynn's Brook Research Station, in western Newfoundland. We compared the accuracy of SMC predictions in a shallow sandy loam-podzol through multi-coil (CMD Mini-Explorer) and multi-frequency (GEM-2) EMI sensors. Three coil separations (32, 71 and 118 cm) with two coil orientations: horizontal coplanar (HCP) and vertical coplanar (VCP) of CMD Mini-Explorer provided six depth layers of ECa. Simultaneously, four factory calibrated frequencies (18, 38, 49 and 80 kHz) were selected for GEM-2 surveys with the data collected by both coil orientations. Kriging interpolated maps were created for the temperature corrected ECa data and point data (n=85) for a 42 m transect in the middle of the test field were digitized. A portable time domain reflectometer was used to measure the volumetric SMC at 0-16 cm depth along the same transect. A simple linear regression analysis between the ECa and measured SMC for 30 data points produced Pearson correlations ranging from 0.39 to 0.94. SMC was then predicted by this regression model for the rest of the ECa data; and a low RMSE range (3.73 to 7.07 %) was calculated for both instruments. The HCP modes of operation have shown better correlation between ECa and SMC than with VCP. The CMD Mini-Explorer was better at predicting SMC than GEM-2, except for VCP32cm. Results indicate that ECa obtained from EMI surveys can be employed to map large scale SMC variability and, with simple calibration models between ECa and SMC for local soils, it can be a promising tool for decision making in precision agriculture.

Preferred Platform: Oral Presentation

Student Presenter: Y

Assessment of the depth sensitivity of multi-coil and multi-frequency electromagnetic induction field-surveys using small buried targets

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Characterizing the depth sensitivity of the electromagnetic induction (EMI) method is essential for near-surface investigations. The apparent magnetic susceptibility (MSus) is a desirable property to investigate depth sensitivity using buried targets of known conductivities. Multi-frequency EMI instruments do provide depth sounding; however, the accuracy of the inferred depth sensitivity is still a matter of debate. The objectives of this study were to: (i) assess the applicability of GEM-2 multi-frequency scans to detect buried targets in shallow soils, and (ii) compare the depth sensitivity of multi-coil and multi-frequency EMI scans using these targets. A small-scale field experiment, over a (4 x 15) m² area, was carried out in western Newfoundland. Materials of different conductivities were buried at 8 distinct locations within a 30 to 80 cm depth range. These include: three hollow metal pieces, plastic bottles filled with either salt water or tap water, and aluminium cans. Four factory-calibrated frequencies (18, 38, 49 and 80 kHz) were selected for the GEM-2 surveys, with two coil orientations: horizontal coplanar (HCP) and vertical coplanar (VCP). Simultaneously, three coil separations (32, 71 and 118 cm) and both coil orientations were used for measuring MSus (in ppt) using a CMD Mini-Explorer probe. High resolution kriging-interpolated maps were created using MSus data in order to identify anomalies from the buried targets. The maximum absolute deviation from the background data was used to quantify strengths of anomalies. The CMD Mini-Explorer clearly detected the four metal targets within 50 cm depth for 3 coil separations and both coil orientations. Three of the metal targets were identified from the GEM-2 data, but weakly. HCP operations produced stronger anomalies compared to VCP, for both instruments. For the tested field in western Newfoundland, the CMD Mini-Explorer shows better accuracy than GEM-2 in depth sensitivity for shallow soils.

Preferred Platform: Oral Presentation

Student Presenter: Y

CSSS_11: Scales and Scaling in Soil Hydrology

Conveners: Asim Biswas¹, Henry Chau², Bing Si³, Sean Carey⁴

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Volumetric water content measurement using hyperbola analysis of GPR in a loamy sand soil

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Reflected wave velocity (v_{rw}) obtained from hyperbola fitting in ground penetrating radar (GPR), can be used to estimate the volumetric water content (θ_v) in soils. This method is applicable only if point reflectors are present in the soil being studied and if clear hyperbolas are present in the radargram. The soil volume of which the hyperbola analysis could optimally describe in terms of v_{rw} is still unclear. The estimated θ_v could be validated using time-domain-reflectometry (TDR), if adequate number of TDR measurements were used to represent the GPR sampling volume. Objectives of this study were to use hyperbola fitting method to; (i) examine the most efficient GPR centre frequency to estimate the depth of shallow reflectors, and (ii) validate the θ_v estimations of GPR common offset (CO) and common-mid-point (CMP) methods. We employed 250, 500 and 1000 MHz centre frequency transducers of PulseEKKO Pro GPR system in a flat land (15 m x 4 m) comprised of loamy sand soil. Six GPR CO surveys were carried out after burying eight different types of point reflectors ranging from 30-80 cm depth. CMP surveys were carried out using 500 and 1000 MHz at each buried location together with a systematic TDR data collection. Twelve θ_v measurements were collected using vertically installed TDR probes (30 cm long) at 10, 20 and 30 cm radii from top of the reflector. Linear regression models of 250, 500 and 1000 MHz ($R^2=0.99, 0.96$ and 0.86 , respectively) suggest that low frequencies have estimated the reflector depth more accurately on a given day. θ_v estimated at 6 locations (30-45 cm depth) using 1000 MHz CMP method gave a strong correlation ($r=0.96$, $p=0.00$ at $\alpha=0.05$, $RMSE=\pm 0.007 \text{ m}^3\text{m}^{-3}$) with the average θ_v measured by TDR at 10 cm radius. θ_v estimations from 500 MHz CO method ($RMSE$ of $\pm 0.019 \text{ m}^3\text{m}^{-3}$ when compared to TDR, and valid up to 80 cm deep reflections) could be considered as the best practical approach.

Preferred Platform: Oral Presentation

Student Presenter: Y

Phosphorus and tracers export pathways described through a four-component hydrograph separation model

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Nutrient loading has impaired water quality in the Missiquoi Bay of Lake Champlain. A key strategic issue is to identify the transport processes delivering phosphorus (P) from upstream agricultural watersheds to the lake, considering the quantity, chemical forms and seasonality of P export. The objective of this study was to develop a method to distinguish surface and subsurface P transport processes, based on the occurrence of baseflow and peak flow events in the streamflow hydrograph and the electrical conductivity (EC) of stream discharge. The stream discharge of Ewing subwatershed (32.2 km²) was separated into surface runoff and subsurface drainage components using EC as an indicator of the cation mass balance, verified experimentally by measuring the electrolytes concentrations and EC in water sampled from surface runoff collectors and tile drainage outlets of 10 agricultural fields in the subwatershed. Subsurface drainage was further segregated into preferential and matrix flow through the soil profile with a computed EC-discharge relationship. The four-component hydrograph model was then used to predict the instantaneous load of P discharged at the subwatershed outlet during fall and spring seasons. Between 46 and 67% of the total P (TP) load originated from surface runoff during peak flow events. Subsurface drainage accounted for 27–29% of the TP load, and preferential flow was responsible for most (75–88%) of the TP load with the remainder coming from matrix flow. Groundwater resurgence accounted for 4–9% of the TP load, while streambank erosion represented up to 21% of the TP load and from 26 to 41% of the particulate P concentration at the outlet. A decline in total suspended solids and dissolved reactive P (DRP) between agricultural fields and the outlet was attributed to in-stream sorption of approximately 30% of the DRP exported from fields.

Preferred Platform: Oral Presentation

Student Presenter: N

Temporal Variability in Groundwater Recharge in Deep Unsaturated Zone

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Groundwater recharge is one of the most important hydrogeological considerations in both water resource management and waste disposal in arid and semiarid regions. However, little is known about the temporal variability and their response to decadal climate variability. The objective of this study is to estimate groundwater recharge using multiple tracers sampled at multiple times and evaluate their response to decadal scale climate variability. Soil Cores were taken at Laura, Saskatchewan in 1996, 2003 and 2017 and Cl, ^3H and Cl concentrations were measured at 20 cm intervals. The groundwater recharge rates has been determined for samples taken in 1996 and 2003 and will be determined for samples taken in 2017, from multiple tracers at the different sampling time. The obtained groundwater recharge rate will be compared with climate variables. The study may indicate how groundwater recharge respond to climate variability at decadal scales.

Preferred Platform: Oral Presentation

Student Presenter: no

Thermography for characterization of soil water repellency at larger spatial scales

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Soil water repellency (SWR) is a natural phenomenon occurring in soils throughout the world. It is a surface property that reduces the attraction of soil for water. Measurement of soil water repellency is done at the point scale; however its role in the environment is often evaluated at the landscape scale. This disparity is due to limitation in the scale of measurements. The objective of this study is improving characterization of soil water repellency at larger spatial scales through thermography. Thermography shows promise to track the temporal and spatial dynamics of soil water repellency. In a lab experiment, it has been demonstrated that there was a huge potential for thermal imaging in SWR mapping to distinguish between highly repellent areas and wettable ones. However, the proposed technique had a number of limitations. One major drawback was its poor performance to detect low SWR areas which is often present in the environment. Another issue is the induction of a temperature gradient to reveal SWR, while also changing the surface properties of SWR. A strategy to help in distinguishing the differences in SWR is to assess the energy balance and evaporative fluxes of the soil surface. A lab calibration experiment will be presented to distinguish the link between thermal regime, evaporative flux, soil water content and soil water repellency. A field survey using thermography to map soil water repellency at larger spatial scales will improve understanding of how SWR can affect hydrologic processes at larger scales. Through this innovative technique, we will be able to predict and model the behaviour of water dynamics in water repellent soil and therefore improve management of water and soil resources. We will further understand the role soil water repellency plays for ecosystem services.

Preferred Platform: Poster Presentation

Student Presenter: No

Soil water dynamics under annual agricultural and perennial bioenergy cropping systems in Ontario

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Sustainable bioenergy production depends upon the efficiency with which crops use available water to produce biomass. Understanding soil water dynamics is thus imperative to predict interactions between bioenergy cropping systems and water resources but information is scarce in Ontario. The objective of this research was to quantify soil water dynamics under annual agricultural and several perennial bioenergy crops grown in Guelph Turfgrass Institute experimental plots. Soil water content was measured weekly to biweekly between mid July and mid November for a total of 11 times in-situ using time domain reflectometry probes at 4 different depths; 10 cm, 20 cm, 30 cm and 50 cm. The measurements were carried out under 4 perennial bioenergy cropping systems (two woody, willow and poplar and two herbaceous; switchgrass and miscanthus) alongside of a native mixed grassland (polyculture) and an annual cropping system (soybean under corn-soybean rotation) with 4 replicated plots (10x10 m). In general, herbaceous cropping (switchgrass, miscanthus, polyculture) system stored more water over willow, poplar or soybeans during mid to late summer. However, soybean stored more water after harvest. Overall the stored water varied significantly ($p < 0.001$) among the cropping systems. Though, the herbaceous cropping systems (perennial bioenergy and native) were not significantly different in storing soil water, they stored significantly ($p < 0.001$) higher amount of water compared to woody perennial and annual agricultural systems. Less intensive rooting system of herbaceous system than woody systems consumed significantly less amount of water. Though this study provides information on the soil water dynamics under different perennial bioenergy and annual agricultural cropping systems, biomass production should be considered in future for estimating water use efficiency and water cycle under these cropping systems.

Preferred Platform: Poster Presentation

Student Presenter: Y

Comparing the hydrophysical properties of an intact 15 cm Sphagnum moss sample to its three 5 cm discrete layers: choosing a representative sample

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What would be more representative of a moss profile: an intact 15 cm sample or three 5 cm discrete layers? The unsaturated hydraulic conductivity (Kunsat) and volumetric water content of sixteen 15 cm samples of Sphagnum moss were measured; the samples were then cut into three 5 cm layers (64 total) and measurements repeated. Considerable differences existed between the 15 cm intact samples and the corresponding combinations (harmonic mean) of the 5 cm layers. For example, at a pressure head of -5 cm, the Kunsat of the combination could be an order of magnitude greater than the intact sample, and VMC 15% higher. The differences in Kunsat and VMC generally decreased with decreasing pressure head. Three scenarios were modelled in HYDRUS-1D to simulate a 2 week continuous evaporation without precipitation: an intact 15 cm sample, a harmonic mean, and a combination of three distinct layers. No consistency was found between the different methods, suggesting that more work is required.

Preferred Platform: Poster Presentation

Student Presenter: Y

A modified algorithm in the SWAT model to describe macropore flow in tile-drained fields

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Soil macropores (cracks, burrows, and root holes) are channels for water movement that bypasses the filtering capacity of the soil matrix. Consequently, macropores can transport significant amounts of dissolved nutrients, including phosphorus (P) ions, through the soil profile to subsurface tile drains, which empty into ditches and surface waterways. Predictions of water and P losses from tile-drained fields depend upon models that partition water movement between three components (surface runoff, macropore flow into tile drains and matrix flow), yet no watershed-scale models do so accurately. The objective was to develop an algorithm that could partition the hydrological flows in an agricultural subwatershed in southern Quebec. We modified the percolation algorithm of the Soil and Water Assessment Tool (SWAT) model to create SWAT-MAC, which adds the option to partition water movement among the three components. The SWAT-MAC predictions were compared with an independent set of results from a chemical-based hydrograph separation of the streamflow into the three components. The modified percolation algorithm decreased the over-estimate of surface runoff as a percentage of annual streamflow, from 33% when the option for macropore flow was not used to 29% when the option was used, compared to 24% as determined by the chemical-based hydrograph separation. SWAT-MAC tended to under-predict macropore flow into tile drains during the periods when crops did not grow or over-predict during the growing season. The model bias suggests that the algorithm does not account for temporal changes in the connectivity between macropores and tile drains. We recommend experimental research to determine the region-specific effects of soil moisture and management practices on macropore flow. By partitioning subsurface water flow into macropore and matrix portions, the modified percolation algorithm provides a basis to improve predictions of water and P transport through tile drains.

Preferred Platform: Poster Presentation

Student Presenter: N

Seasonal dependent time stability of soil water storage within a maize cropped field

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Spatial patterns of SWS may exhibit a similarity over time which has been identified as time stability. Knowledge of the time stability and its scale and location dependency in crop grown fields is necessary to understand the dominant processes controlling SWS variability and their seasonal dependency, but the information is lacking. This study examined the overall and scale and location specific time stability of soil water storage (SWS) patterns at surface depths in a maize cropped field. SWS was measured at 0.05, 0.10 and 0.20 m depths along 128 locations of six transects over a crop growing period using the actively heated fiber optics method in the Coteau du Lac area, Quebec, Canada. High rank correlation coefficients indicated a strong intra-seasonal time stability of SWS patterns at the measurement scale. Wavelet coherency analysis also showed a strong intra-seasonal time stability, but at different scales and locations. Stronger intra-seasonal time stability observed all scales and locations during the summer season (22 July and 11 August) was associated with the processes such as evapotranspiration and high crop water uptake. Weak inter-seasonal time stability between the summer and fall seasons showed change in the processes controlling the spatial patterns of SWS in the maize crop field. Strong intra-seasonal time stability observed between 01 October and 15 October at medium (4-8 m) to large (10 m) scales at 0.10 and 0.20 m depths revealed the impact of preferential flow patterns on SWS spatial patterns at those depths during the recharge period. Overall, results of this study indicated that the time stability of SWS is seasonal and depended on the dominant processes operating during the dry (summer) and wet (fall) periods.

Preferred Platform: Poster Presentation

Student Presenter: Y

CSSS_12: Conveying Analytical Methods and Method Development in Soil and Environmental Sciences

Conveners: Jessica Stoeckli¹ and Katelyn Lutes¹

Co-chairs: Jessica Stoeckli¹ and Katelyn Lutes¹

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Using advanced techniques to characterize phosphorus in Mehlich 3 soil extracts

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Soil test phosphorus (STP) is routinely measured to estimate P fertilizer requirements for crops. There are a number of different methods available for use depending on the soil pH and regional preferences. The Mehlich 3 method is becoming increasingly popular throughout Canada and the USA, and allows the measurement of both STP and exchangeable cations. The P concentration in the Mehlich extracts can be measured colorimetrically or with inductively coupled plasma-based spectrometry (ICP); however, the results can be very different with these two techniques. The concentrations determined by ICP are usually higher than those by colorimetry, because ICP determines total P in solution and colorimetry only measures orthophosphate. However, ICP values are not always higher, and there is no consistent pattern with respect to soil characteristics to predict when the values will be different. This can affect the fertilizer recommendations. To better understand the P extracted by the Mehlich 3 method, we characterized the P forms in extracts using advanced techniques (^{31}P nuclear magnetic resonance (NMR) spectroscopy and mass spectroscopy) on soils from different locations and with different treatments. Our results showed that Mehlich 3 will extract phytate from soils, especially soils where phytate is stabilized by cations (e.g. by Al with alum). Because phytate is not plant-available, ICP analysis will over-estimate plant-available P in soils with high phytate concentrations in Mehlich 3 extracts. This research demonstrated that advanced techniques can be used to better understand simpler techniques, to refine existing techniques or develop new methods.

Preferred Platform: Oral Presentation

Student Presenter: N

Land use and tillage effects on soil hydraulic properties: Does infiltration method matter?

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Land use and tillage are important factors influencing soil hydraulic properties. However, associated results are usually controversial partly due to different measurement methods involved. The aim of this study was to explore whether measurement method affects the response of soil hydraulic properties to land use and tillage. For this purpose, infiltration experiment were done two times (i.e. pre-tillage and post-tillage) at the surface layer of two land uses (i.e. pasture and cropping land) in a silt loam textured soil at Lincoln, New Zealand. Based on the scoring with seven criteria including cost, operation, and information content, four methods, including one lab method (constant head and tension table with intact core, IC) and three field methods (Beerkan Estimation of Soil Transfer, BEST; tension infiltration, TI; double ring infiltration, DRI) were used to obtain saturated hydraulic conductivity (K_s), unsaturated hydraulic conductivity (K_{un}) (except for DRI method), and soil water retention curves (with IC and BEST methods only). Overall, method and tillage did not affect K_s , while cropping land had significantly higher LgK_s value than pasture land (LgK_s of 1.31 versus 1.16 mm h⁻¹). However, methods had significant ($p < 0.001$) interaction with land use and tillage, indicating that land use and tillage effect on K_s was affected by method. The field methods corresponded to higher K_s value in cropping land and post-tillage, whereas the lab method showed the opposite. Memory of the tillage effect on K_s was retained for K_{un} . The BEST and TI methods corresponded to higher K_{un} for post-tillage, while the IC method showed the opposite. The BEST method underestimated soil water content, partly because of the overestimation of shape parameter n and underestimation of sorptivity due to the high initial soil water content. This study indicates that method can influence the response of hydraulic properties to land use and tillage effects, and methods (i.e. field or lab method) should be selected depending on the particular application purpose.

Preferred Platform: Oral Presentation

Student Presenter: No

Comparative Acetylene Reduction Assay and $^{15}\text{N}_2$ direct assimilation methods in peatlands

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The Acetylene Reduction Assay (ARA) is considered a sensitive and widely applicable method for measuring biological nitrogen fixation (BNF). It is an indirect method, and originally it was established that a conversion factor (CF) of 3:1 needs to be applied to convert ethylene production into BNF. More recently, it has been concluded that it is necessary to estimate the CF for each specific site by comparing the ethylene produced to the direct assimilation of $^{15}\text{N}_2$. However, it is not clear the reliability of the ARA method in peatlands even by calculating the CF. Here we report a significant underestimation and even inhibition of BNF using the ARA method. We measured BNF, using the ARA and the direct $^{15}\text{N}_2$ assimilation methods, in three different peatlands across Britain during the growing season. The incubations were carried out in parallel on the dominant Sphagnum spp (*S. cuspidatum*, *S. fallax*, *S. capillifolium*, and *S. papillosum*) and top bulk peat (0-15 cm). Also, it was measured methane production, and additional incubations were performed using the direct $^{15}\text{N}_2$ assimilation method with and without acetylene. The results show that the CF can vary from 0.43 to 113.5 in Britain, with a difference up to 84 in the same location in different years. Regarding species, the CF was also highly variable ranging from 0.0062 in *S. papillosum* to 131 in *S. capillifolium*. The differences found between the ethylene production (ARA) and the direct $^{15}\text{N}_2$ assimilation range from 11 to 256 times lower the former than the latter. The methane production shows a significant negative relationship ($P < 0.05$) with ethylene production, suggesting that the inhibition of the methanotrophy affects BNF. The differences in BNF using the $^{15}\text{N}_2$ assimilation method were significantly lower adding acetylene. The range was from 4 to 140 and even, in some cases, several species showed no BNF with acetylene. These findings suggest that ARA is not a method to rely upon to measure BNF in peatlands.

Preferred Platform: Oral Presentation

Student Presenter: Y

Trust me (my data), it is a good idea to measure specific surface area

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Weathering of mineral soil is a fundamental process providing nutrients for vegetation. In forested regions of Canada, and particularly those where biomass harvesting represents an important export of calcium, magnesium, and potassium, resupply of these elements via mineral weathering is critical to long-term ecosystem health. Weathering rates are quantified in a variety of ways, including empirical observations, predictive relationships and process-oriented models; however, each suffers one or more limitations. Because weathering reactions only occur on wetted and exposed surfaces of weatherable minerals, surface area is a key determinant of weathering rate, but a property that is challenging to quantify accurately. The pitfalls of using predictive relationships to estimate surface area of coarse-textured soils from other properties will be demonstrated using data from a large number of sites in North America and Europe. The error associated with these predictions is shown to translate to several orders of magnitude uncertainty in process-oriented model derived weathering rates. As a way forward from pedotransfer functions derived estimates of surface area, the feasibility of quantifying soil surface area through two different chemical adsorption methods, aqueous p-nitrophenol and gaseous nitrogen, was explored. In contrast to studies for other soil types, the two adsorption methods did not show strong agreement. Direct measurement via nitrogen adsorption is recommended for quantifying surface area of coarse-textured soils. Further, paired measurements of bulk soil (with organic matter), and soil after chemical oxidation of organic matter demonstrated reasonable agreement suggesting that analysis of (raw) bulk soil should be considered as an alternative to past approaches that seek to isolate mineral surfaces prior to analysis of surface area.

Preferred Platform: Oral Presentation

Student Presenter: N

Quantifying fluxes of soil N₂O emitted after rain-on-frozen-soil events

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Nitrous oxide (N₂O) emitted from soil is a major concern, due to its high global warming potential and ozone-depleting properties. Pulses of N₂O are emitted from agroecosystems after thawing of frozen soil, due to physical release of N₂O present in the soil profile and from de novo biological production in saturated soil. When rain falls on the surface of a frozen soil, it has potential to induce similar soil biophysical processes as a freezing-thawing cycle, but the magnitude of N₂O fluxes from rain-on-frozen-soil events has not been determined. The objectives of this study were (1) to quantify the N₂O flux from a rain-on-frozen-soil event, and (2) to distinguish the N₂O released from physical diffusion versus biological processes under these conditions. A controlled laboratory experiment is conducted to evaluate the N₂O flux from cores containing frozen soil as a function of rainfall intensity (0, 2, 5, 10 and 20 mm hr⁻¹), due to the impact of rainfall on conductive heat transfer at the frozen soil surface and water-filled pore space. Surface soil is frozen unidirectionally in a microcosm system and ¹⁵N-N₂O is injected below the frozen soil surface. After the rainfall event, the N₂O fluxes are determined in relationship to rainfall intensity. The ¹⁵N-N₂O / ¹⁴N-N₂O ratio is used to quantify the contribution of entrapped N₂O and de novo biological production to the N₂O flux. The results will provide fundamental knowledge of biophysical controls on N₂O fluxes after rain-on-frozen-soil events, which is currently missing from field-scale models of denitrification such as the DeNitrification-DeComposition (DNDC) model.

Preferred Platform: Poster Presentation

Student Presenter: Y

CSSS_13: General Soil Sciences

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Assessing the Sustainability of Soil Management in Canada [Invited]

Dan Pennock

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Over the past five years the Food and Agriculture Organization (FAO) of the United Nations has adopted a new and more expansive definition of Sustainable Soil Management (SSM). The new approach broadens the scope of SSM to include explicitly the effect of soil management on ecosystem services such as the regulation of water quality and greenhouse gas emissions. This differs from assessments of soil health or quality, which are almost invariably soil centric. The proposed assessment protocol for SSM must allow the fundamental question that underlies the work of the FAO to be answered – is global adoption of SSM increasing or decreasing? In Canada, we have a well-established (and arguably world-leading) process for assessing the impact of agriculture on the environment through the Agri-Environmental Indicators (AGI) series. The data from the AGI series can be used to both assess the regional-scale sustainability of agricultural soil management in Canada and highlight the issues that impede the adoption of SSM.

Sorption and Sorption Kinetics of Sulfamethoxazole on Cattail and Switchgrass Roots as a Mechanism for Attenuation

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The role of plants in the attenuation of antibiotics in wetland and terrestrial systems constructed for in-situ removal of nutrient and trace element contaminants is currently undefined. Sulfamethoxazole is a frequently detected antibiotic in treated wastewater and biosolids. Cattail and switchgrass are high biomass yielding plants and have the potential of removing antibiotics during the phytoremediation of other contaminants. The objective of this study was to characterize the sorption and sorption kinetics of sulfamethoxazole by cattail and switchgrass roots. A batch sorption experiment was conducted to measure the sorption of sulfamethoxazole by roots of the two plants using five initial antibiotic concentrations (2.5, 5, 10, 15 and 20 $\mu\text{g L}^{-1}$) and at eight time steps (0, 0.5, 1, 2, 4, 8, 12 and 24 h). To determine the effect of temperature on sorption kinetics, a batch sorption study was conducted using an initial antibiotic concentration of 5 $\mu\text{g L}^{-1}$ and three temperatures (5, 15 and 25 $^{\circ}\text{C}$). The Freundlich isotherm provided the best fit for the sorption data, indicating multi-layer sorption. The Freundlich constant (K_f) was significantly greater for switchgrass (71.3 ($\mu\text{g g}^{-1}$) ($\text{ml } \mu\text{g}^{-1}$) $1/n$) than for cattail (24.5 ($\mu\text{g g}^{-1}$) ($\text{ml } \mu\text{g}^{-1}$) $1/n$). Sorption kinetics of sulfamethoxazole was best described by the pseudo-second-order kinetic model. The effect of temperature on the rate constant (k_2) and on the amount of sulfamethoxazole sorbed at equilibrium varied with the plant type. The k_2 decreased with increasing temperature in both plants. Results from this study show that switchgrass roots are more effective than cattail in the removal of sulfamethoxazole and hence the use of switchgrass in systems designed for the phytoremediation of contaminants from media such as biosolids might also provide for an efficient removal of some antibiotics.

Preferred Platform: Oral Presentation

Student Presenter: Y

Modelling of biosolids originated phthalate esters (PAEs) dynamics in outdoor lysimeters planted to grain corn

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The ubiquitous use of phthalate esters (PAEs) has resulted in their potential to reach groundwater sources through application of agri-chemicals and municipal biosolids. A study was conducted to model the fate and transport of seven commonly detected PAEs in the environment including: dimethyl phthalate (DMP), diethyl phthalate (DEP), benzyl butyl phthalate (BBP), bis(di-ethyl hexyl) phthalate (DEHP), di-n-octyl phthalate (DnOP), dipentyl phthalate (DPP), and di-n-butyl phthalate (DnBP). Biosolids sourced from the Halifax Regional Municipality were applied on field-based lysimeter cells which were planted to corn (*Zea mays*) for a growing season. The HYDRUS-1D code and a two-site sorption model were applied to simulate governing process of PAEs transport using both PAEs breakthrough curves (BTCs) and soil profile concentrations data. Results revealed that higher PAE adsorption was observed based on increasing carbon chain number. In addition, higher values of F (i.e. the fraction of type-1 sorption sites assumed to be in equilibrium with the solution phase) and lower values of D (i.e. dispersion coefficient) were observed for PAEs with large carbon chains which was validated both through the empirical dataset and the model simulations. For all PAEs, F and D parameters showed an indirect relationship with carbon chain and chemical structure. In the case of PAEs with $\text{Log } K_{ow}$ (octanol–water partition coefficient) <5 , similar results were obtained for K (partition coefficients) and k_2 (first-order sorption rate coefficient) parameters. While, for PAEs with $\text{Log } K_{ow} >5$, as it increased a sharp decline was observed in the values of K and k_2 which attributed to colloid-facilitated transport of PAEs. As a summary, the two-site sorption model has considerable capacity to simulate and predict transport and leaching of PAEs from soil amended with municipal biosolids under grain corn.

Preferred Platform: Oral Presentation

Student Presenter: N

Impacts of corn stover removal on carbon dioxide and nitrous oxide emissions

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Corn stover for cellulosic sugar production is new value added product that farmers are considering selling in southern Ontario. The question is how much corn stover can be removed from soils sustainably. A field project was initiated in the fall of 2014 on a sandy loam soil under no tillage and conventional tillage. The residue treatments include 0%, 25%, 50%, 75% and 100% corn stover removal. Carbon dioxide emissions were found to decrease with increasing corn stover removal rates. Carbon dioxide emissions were also considerably greater under conventional tillage compared to no-tillage. Nitrous oxide emissions however increased with increasing removal rates in 2015, a wet growing season, whereas removal rates did not have as great an impact on nitrous oxide emissions in the 2016 and 2017 growing seasons.

Preferred Platform: Oral Presentation

Student Presenter: N

The effect of organic amendments and post-harvest deficit irrigation on the expansion of sweet cherry production under climate change in the Okanagan

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In the Okanagan Valley, sweet cherry production has expanded to higher elevations and latitudes due to climate change, but water availability and maintenance of soil health are major concerns for sustainable production. This study examined the effects of organic amendments (OA) and post-harvest deficit irrigation (PDI) on soil health, tree productivity and fruit quality in newly and previously established cherry orchards over two years (2016-2017). Sweet cherry trees were planted at three locations in a randomized block, split-plot experimental design with six replicates. Two irrigation treatments (100% and ~70% water supply) were the main plots, with three soil treatments (compost, mulch and bare ground) as sub-plots. Organic amendments, particularly compost, increased soil and foliar minerals, and decreased arbuscular mycorrhizal colonization and total fungal populations compared to bare plots. Compost increased fruit colour and stem pull force and maintained fruit firmness, while mulch increased soluble solids concentrations during the second year. The application of PDI did not affect cherry tree stem water potential, tree growth or soil health properties. These results suggest that OA are a promising strategy to improve fruit quality, plant and soil nutrients, and PDI has the potential to reduce water use after harvest without affecting cherry production.

Preferred Platform: Oral Presentation

Student Presenter: Y

Assessment of soil health indicators on organic farms in southwestern Ontario

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Despite interest from growers to assess soil health, there is limited information on the efficacy of different tests on working farms. In cooperation with the Ecological Farmers Association of Ontario's Farmer-led Research Program, three organic growers in southwestern Ontario tested the sensitivity and reproducibility of 20 indicators. By taking five replicate soil samples of ten composite cores (2.2 cm diameter, 0-15 cm depth) from different fields on each farm, we compared soil health indicators in fields of grower-perceived high and low productivity and a reference area (permanent cover fence row). Growers based these perceptions on observations of biomass and species composition in pastures (Lucknow, clay loam (Podzol; Grey Brown), hay yields (Dundalk, silt loam (Podzol; Grey Brown) and vegetable yields (St. Thomas, sandy loam (Brunisol; Gray Brown Luvisol)). Soil samples were shipped on ice to commercial labs for analysis. For each farm separately, we tested sensitivity using ANOVA ($\alpha = 0.05$) and reproducibility using power analysis. Active C (permanganate oxidation method) and nitrate distinguished between production fields and reference sites at all farms. Active C also ranked the fields (highest = reference, lowest = low productivity). Inorganic P, Haney test N, Haney's soil health calculation and water extractable organic N distinguished between fields of high and low productivity but not reference sites. Active C, nitrate, inorganic P and Haney test N were reproducible, requiring at most 6 replicates to achieve a power of 95%. Soil organic matter (loss-on-ignition) was highly reproducible ($n=3$ at 95%) for differences greater than 0.5%OM. Our results were consistent with previous research that showed grower perception of soil quality correlated with management-sensitive soil health indicators. Growers intend to use results to help guide land management decisions towards improved soil health.

Preferred Platform: Oral Presentation

Student Presenter: N

Soil Strength and Density of Solonetzic and Chernozemic Soils as Affected by Subsoiling and Vertical Tillage in South-Central Saskatchewan

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Wet field conditions in recent years and associated concerns about compaction and residue management in some prairie soils has led to increased interest by growers in a strategic tillage operation. The objective of this study was to evaluate the effect of subsoiling wheel traffic compacted soils and using vertical tillage to manage crop residue using field scale equipment in farm fields in south-central Saskatchewan. Annually cultivated Solonetzic and Chernozemic soils subjected to heavy wheel traffic compaction were selected and a minimum-till subsoiler operated at a depth of 30 cm was used to impose subsoiling tillage treatments in the fall of 2015 in replicated RCBD trials. To evaluate effects of surface tillage practice, vertical and conventional tandem disc tillage treatments were applied in fall of 2015 on an annually cultivated Chernozem after flax harvest. Compaction induced by repeated wheel traffic (field haul roads) increased soil strength and density in the top 20cm and reduced air and water permeability, with negative effects most evident on the soils that were poorly structured to begin with (Solodized Solonetz), and less apparent on the better structured (Chernozemic) soils. Subsoiling in fall of 2015 significantly reduced soil strength and soil density measured in 2016 in the compacted and non-compacted areas. A natural recovery from compaction was also observed, as strength and density decreased over time in non - subsoiled treatments. The effect of subsoiling on reducing soil strength was still apparent in the second year (2017) after treatments were imposed. Vertical tillage had less effect and mainly influenced soil properties in the top 20 cm, such as reducing air permeability. Yield benefits from tillage were only significant in the Solonetzic soil, where subsoiling of long-term wheel traffic compacted zones increased canola yield in 2016. No significant yield effects were observed in 2017.

Preferred Platform: Oral Presentation

Student Presenter: N

Dynamics of emerging substances of concern in agricultural field soils after six years of biosolid applications

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Results from a long-term biosolid application study in Nova Scotia will be presented with an emphasis on monitoring the presence of emerging substances of concern (ESOC). Soil samples were collected over different points in the growing season from 2009 to 2014 in plots receiving annual applications of alkaline treated biosolid (ATB) at rates of 0, 14, 28 and 42 Mg ha⁻¹. Over the initial four years, the experimental plots were grown in corn and for the subsequent two years in barley. Soils were analyzed for gemfibrozil, diclofenac, warfarin, caffeine, norfloxacin, carbamazepine, and dimethylxanthine at one month post-application of the biosolid treatment and at post-harvest for each year. Significant concentration differences between ATB rates and over years within each sampling period were found for most of the ESOCs measured in the soils. Over the six year period, ESOC concentrations increased linearly for most compounds measured. The relationships found from this analysis suggests that changes in soil properties, accumulation of organic matter, and potentially shifts in microbial activities from intensive applications of ATB have played a role in supporting retention of these chemicals in the soil.

Preferred Platform: Oral Presentation

Student Presenter: no

Applications of the Field Capacity Concept

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It has been known for decades that the field capacity (FC) concept includes four main components, namely drainage rate or flux (q), drainage time from saturation (t), drainage depth (z), and soil water content in the drained zone (θ). Despite this, FC is usually defined as the water content at a pore water tension head (h) that is either specified (e.g. $h = 1$ m) or derived from the shape of the soil water desorption curve. In addition, rather little work has been done to incorporate the four FC components into analytic expressions, or to determine how such expressions are best used in applications of the FC concept. This presentation will present simple analytic expressions that account for all four FC components, test the accuracy of the expressions against numerical simulations, and illustrate how analytic FC expressions might be used in agronomic and environmental applications. The analytic FC expressions were able to predict q and θ within 36 % of numerically determined values for $t \geq 0.01$ day and $z = 0.03$ m or 1.0 m, which is considered sufficiently accurate for most FC applications. The expressions also showed that all four FC components are important; that most FC applications have both agronomic and environmental implications; and that FC definitions based on desorption curve shape or specified tension head are frequently inaccurate. It is proposed that the FC concept is most appropriately applied in crop production studies by using integrative FC expressions like those presented here to optimize air and water storage, drainage flux, drainage time, and potential nutrient leaching rate in the crop root zone.

Preferred Platform: Oral Presentation

Student Presenter: N

Mechanism of water recharge in very deep soil on the Loess Plateau of China

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The recharge mechanism of groundwater is of great significance for the utilization of agricultural water resources on the Loess Plateau of China. Due to the use of indirect method in studying groundwater recharge, controversy still exists in this subject. In this work, chloride and nitrate were used as tracers to reveal the movement of water in deep soil layers (10 m). Results show that the average annual recovery of deep soil water storage (3-10 m) amounting to 7.5-15.3% of the multi-year average precipitation (580 mm) after apple orchards converted into croplands. The front waves of water movement were ahead of the front waves of the tracers' movement, evidence of preferential flow has not been found. The new precipitation pushes down the original water in the soil, resulting in an increase in water content in the deeper soil layers.

Preferred Platform: Oral Presentation

Student Presenter: Y

Effect of Subsurface Tillage on Soil Physical Properties in a Solonetzic Soil

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Questions have arisen about the long-term effectiveness of subsoiling tillage to address soil physical limitations in naturally dense Solonetzic subsoils in order to increase plant yields. Reclaiming sodic soils with hardpan B horizons may be possible through subsoiling to loosen the B horizon to improve permeability, reduce soil strength and soil bulk density and increase water infiltration. The objective of this study was to determine the effects of subsoiling on long-term wheel-traffic compacted dense Solonetzic soils on aggregate size, bulk density, soil strength, air and water permeability, and crop yield in an annually cultivated field in southern Saskatchewan, Canada. Subsoiling of the compacted Solonetzic soils significantly reduced bulk density and soil strength in all treatments, and increased air permeability to 1.15×10^{-6} m sec⁻¹ compared to 9.78×10^{-7} m sec⁻¹ in the non-subsoiled treatment. Subsoiling of the compacted Solonetzic soil increased canola grain yield to 2681 kg ha⁻¹ compared to 1544 kg ha⁻¹ in the non-subsoiled treatment. The lifting and shattering action of the subsoiler implement improved soil physical attributes in the compacted Solonetzic soil which had a positive effect on plant yields.

Preferred Platform: Poster Presentation

Student Presenter: Y

Multi-hierarchical selection of soil resistance genes in arable soil amended with cephalosporin mycelial dreg

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Cephalosporin mycelial dreg (CMD) is a byproduct of the pharmaceutical industry that may be disposed through land application. While beneficial for soil physico-chemical properties, the possibility of CMD-induced antibiotic resistance in the native soil microbial community still needs to be investigated. The objective of this work was to evaluate the development of antibiotic resistance in arable soil amended with CMD. In a lab-based pot study, the CMD-induced selection process for soil resistance genes, including changes in the overall structure of bacterial populations and additional antibiotic selection, was determined with quantitative PCR array and Illumina sequencing. β -lactam resistance genes were detected with significantly increased abundance and distinct patterns, and mobile genetic elements (MGEs) enriched in the CMD amended soil compared to the unamended control soil. Marked shifts in bacterial abundance and composition were observed, with taxa of the Proteobacteria, Actinobacteria, Bacteroidetes and Gemmatimonadetes being the most responsive to the temporal succession of resistance genes, suggesting an indirect selection of bacteria conferring resistance. The diversity and abundance of resistance genes exhibited temporal shifts and the MGEs were more strongly correlated to raw-CMD amended soil than treated-CMD amended soil, indicating that antibiotics introduced by CMD contributed to the direct selection of resistant microorganisms. These results imply a multi-hierarchical selection process of soil resistance genes following the application of CMD to arable soil.

Preferred Platform: Poster Presentation

Student Presenter: Y

Influence of manure and compost additions on the water repellency of tropical soils

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Soil water repellency is a major concern in many systems as it substantially reduces infiltration and enhances surface runoff. While it is recognised that repellency is affected by the soil organic matter content in natural ecosystems, the impact of manure and compost additions on the development and persistence of repellency in agroecosystems, particularly in the tropics, is poorly understood. We therefore examined the impact of different manure, compost additions on soil water repellency of tropical soils. We monitored the change in repellency in three different soil types, amended with three manure-compost types at three different concentrations and four temperatures. Soil water repellency was the strongest among soils with higher clay content due to the inherently higher organic matter. The cattle manure produced the most severe repellency despite having the lowest total organic carbon, while the sugarcane-bagasse produced the lowest repellency. This work also highlighted the importance of plant compost in reducing the level of repellency caused by cattle manure while still having a positive influence on the nutrient status of soils.

Preferred Platform: Poster Presentation

Student Presenter: N

Effectiveness of Organic and Inorganic Amendments on Stabilization of As, Cd, Cu, and Zn in Metal Contaminated Soils

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Addition of organic and inorganic amendments are known to have immobilizing effects on heavy metals. In this study we tested stabilization of heavy metals from contaminated soils by selected organic and inorganic amendments. Soil from a Cu-Zn smelter in Flin Flon, MB, contaminated with As, Cd, Cu and Zn was used for the study. A laboratory incubation study was conducted with contaminated soil alone or mixed with either biochar (5% w/w), compost (5% w/w), nano-Fe-Oxides (Fe-O; 0.2% w/w) or diammonium phosphate (DAP; 0.2% w/w), at field-capacity moisture for six months. At the end of the incubation period soil was extracted sequentially for As, Cd, Cu and Zn. Biochar, compost, Fe-O and DAP reduced availability of As from contaminated soil while biochar and Fe-O reduced Cd availability. Cu availability was reduced by all amendments while Zn availability reduced by biochar, DAP and Fe-O. Since the effectiveness of amendments in reducing metal bioavailability varied depending on the metal, combination of amendments may be more effective for remediating multi-metal contaminated soils, which needs further investigation, preferably under field conditions.

Preferred Platform: Poster Presentation

Student Presenter: N

Soil health in organic grain cropping systems as influenced by agronomic management and weed presence

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In organic production systems, frequent tillage to control weeds and the low crop residue returned to soil may negatively affect soil health. Few studies have examined soil health as impacted by the previous green manure (GMr) crop, plus the species diversity and richness of weeds present in the crop phase. From 2016 to 2018 in Truro, Nova Scotia organically crop rotations were managed with soybeans, wheat and various GMr including red clover, hairy vetch or common vetch under-seeded with oats. The experiment had a randomized complete block design with a split-plot component to designate weedy and non-weedy subplots for comparison. Aboveground weed, crop biomass and soil were sampled during both growing seasons. This project examined soil health following the Cornell Soil Health Assessment (CSHA) framework including: surface and subsurface hardness, available water capacity and aggregate stability, pH, and available potassium (K), phosphorus (P), zinc (Zn), magnesium (Mg), iron (Fe), soil respiration, autoclaved citrate extractable (ACE) soil protein index, total nitrogen, organic matter (OM) and active carbon. Non-mycorrhizal wild radish (*Raphanus raphanistrum*) was the most predominant weed species found in both years, irregardless of the previous GMr. However, during the second year of analysis, there was a slight shift of increasing relative proportions of bristly foxtail (*Setaria viridis*) in the plots that had a previous GMr of red clover 2 years prior. The average dry weed tissue biomass was 2.58 (± 0.08) t/ha in 2016 growing season and 0.79 (± 0.02) t/ha in 2017 respectively. The previous GMr in crop rotation had a significant effect on the wet aggregate stability of the soil over a 2-year period ($P=0.003$), with highest values using red clover and lowest values with NoGMr. The crop rotation phase (actually having no GMr) and the non-weedy condition significantly increased the soybean dry biomass weight/plant ($P<0.001$ and 0.0051 respectively). The presence of weeds reduced soybean crop yields in half. However, the weeds did not affect any measured attributes of soil health ($P\geq 0.05$). Future research would conduct longer crop rotations to test for additional effects on the soil properties over time.

Preferred Platform: Poster Presentation

Student Presenter: Y

Improved potato agronomy to enhance potato yield and soil quality

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It is challenging to maintain soil productivity and soil quality under potato-based systems due to frequent and intensive soil tillage and low C carbon inputs. This 4 years (2014-2017) study investigated the impact of improved potato agronomy on potato yield and quality and on selected soil quality parameters. Five different treatments were compared and included; three 2yr potato rotations: i) japanese millet-potato (JM-P) with conventional plowing before potato seeding (plowing, disking and and harrowing); ii) japanese millet-potato with rough tillage (no disking) JM-rP) before potato seeding; iii) potato-soybean with direct seeding soybean without tillage (P_rsoy) ; iv) a 3 yr (common) potato rotation with barley underseeded with red clover-red clover-potato (B-Cl-P) with conventional tillage before potato; v) a rotation with two potato harvests every five years with barley underseeded with red clover-red clover-potato-soybean-potato (B-cl-rPr-S-rPr) where winter rye is broadcast after potato harvest and direct seeding soybean in the crimped and rolled winter rye in the following spring and rough tillage before potato seeding (no disking). All rotation phases were implemented every year with 3 replications. The P_rsoy rotation was associated with lowest potato marketable yield, whereas, the highest yield tended to be associated with the JM-rP with other rotations showing comparable values. The JM-P and the P_rsoy rotations showed around 20% higher surface hardness values than other rotations. There were trend towards higher nominal values of SOM in the longer potato rotations ((B-Cl-P and B-cl-rPr-S-rPr) . No effect of the rotation was observed on aggregate stability. Preliminary results demonstrated that rotating potato with soybean may not be sustainable in the long-term and that including a high carbon content (millet) crop with reduced tillage intensity could represent benefits on potato yield and soil quality.

Preferred Platform: Poster Presentation

Student Presenter: No

Can mixtures conserve soil water and avoid the setbacks of cereal cover crop monocultures?

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Cereal rye (*Secale cereale*) is among the most popular cover crops (CC) used by farmers today, and several studies have documented its capacity to conserve soil water during the following corn growing season. However, its use comes with a number of setbacks, most notably early-season nitrogen deficiency in the subsequent corn crop resulting in yield loss, and unreliable biomass production. In order to minimize the effect of the former, farmers are forced to terminate the CC earlier and so end up with substantially less biomass production, in which case water conservation effects are either unobservable or non-existent. A CC mix may be able to harness the positive characteristics of cereal rye while also avoiding its setbacks. To address this, an experiment with a collaborative farmer from Dresden, Ontario, was established in 2016 to compare soil water dynamics in corn following a bare fallow treatment, a cereal rye cover, and a four-species mix including cereal rye, crimson clover (*Trifolium incarnatum*), Japanese millet (*Echinochloa esculenta*), and sunflower (*Helianthus annuus*). The experiment also employed ambient, drought, and irrigated sub-treatments to assess if soil water dynamics changed when water was more or less available. After the first experimental year, no significant difference in spring residue area index was found between the rye cover and the four-species mix ($p=0.3046$), suggesting that both provided a similar surface mulch for preventing evaporative water loss. Corn yield was not significantly different between rye and the mix at ambient and irrigated water levels but was significantly lower after rye when water was limiting ($p=0.0176$). Soil water storage data is still being analyzed, and the study is being repeated in 2018 to clarify these effects.

Preferred Platform: Poster Presentation

Student Presenter: Y

Role of endophytic diazotrophic bacteria in promoting the growth of lodgepole pine at extremely N-deficient gravel mining pits in Central Interior BC

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Lodgepole pine trees can be found growing well throughout British Columbia, even on rocky substrates like unreclaimed gravel mining pits. Soils at these pits are gravelly in texture with weak profile development, lacking soil horizons and organic forest floor. Such soil conditions make these pits one of the most nitrogen (N)-limited sites on which trees have been observed to grow. However, it has been reported that tissue N content and growth rate of pine trees are unaffected by low soil N levels at these pits. This indicates that pine trees could be meeting their N requirements from a source other than soil N. A possible source could be the biological N fixation (BNF) from the atmosphere. In this study, I looked at the possibility of BNF by those N-fixing bacteria that can live inside the plant tissues (endophytic diazotrophic bacteria).

Lodgepole pine trees were collected from two gravel mining pits located in the Central Interior BC (52°09' N 123°10' W; 52°18' N 121°53' W). The objectives of this study were: to isolate and identify potential endophytic diazotrophic bacteria from young lodgepole pine trees growing at these pits; and to examine their N-fixing ability by using acetylene reduction assay (ARA).

Seventy-seven potential endophytic diazotrophic bacteria were isolated from pine trees using N-free culture media. They belonged to the genera: *Bacillus*, *Frigoribacterium*, *Paenibacillus*, *Pedobacter*, *Pseudomonas*, *Rhizobium*, and *Rhizobium*. Out of the 77 isolates, 32 were tested positive in ARA thus confirming their N-fixing ability. Based on these results, it can be concluded that N-fixing bacteria reside in the internal tissues of lodgepole pine trees at these extremely N-limited gravel pits and they could be involved in fulfilling the N requirements of pine trees. Henceforth, these bacteria will be inoculated into pine trees to determine their ability to recolonize pine and examine the amounts of N-fixed in a yearlong greenhouse experiment.

Preferred Platform: Poster Presentation

Student Presenter: Y

Characterization of N-fixing bacteria isolated from internal tissues of lodgepole pine and hybrid spruce trees growing in West Chilcotin region of BC

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West Chilcotin is a remote region located in BC Interior where cold climate and low annual precipitation have resulted in relatively dry and weakly developed soils (particularly, nitrogen (N) deficient), which has led to a very slow tree growth. Most common tree stands are lodgepole pine and hybrid white spruce and due to their ability to grow on such nutrient-poor soils, N-inputs in these forests has been a long-standing conundrum. I hypothesized that N fixation by bacteria living inside plant tissues (known as 'endophytic diazotrophic bacteria') is a source of N nutrition for trees growing in this region. To test this hypothesis, I selected two sites with different soil moisture contents in a predominantly pine stand and collected soil and plant samples from each site. Similarly, soil and plant samples were also collected from two sites with different soil moisture contents in a predominantly spruce stand. The objectives of this study were: (i) to compare the nutrient contents of soils collected from high-moisture and low-moisture sites in each stand; (ii) to isolate and identify potential endophytic diazotrophic bacteria from pine and spruce trees growing at these sites; and (iii) to examine their N-fixing ability using acetylene reduction assay (ARA). Results of soil analyses revealed that soil nutrient content (especially, available and mineralizable N) at low-moisture sites was significantly lower than at high-moisture sites in both stands. Forty-eight and 55 potential endophytic diazotrophic bacteria were isolated from pine and spruce trees, respectively and identified as mainly belonging to genera: *Bacillus*, *Burkholderia*, *Paenibacillus* and *Pseudomonas*. ARA results indicate that pine and spruce trees growing in this region harbour naturally occurring N-fixing bacteria in their tissues, possibly to gain fixed N. I will be further investigating these strains in planta to confirm their N-fixing ability and quantify fixed N they can provide to pine & spruce.

Preferred Platform: Poster Presentation

Student Presenter: Y

Adaptation of a crystallization inhibition technique for brine remediation in fine textured soils

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Roughly 14,800 saline produced water (brine) spills have occurred on lands utilized in Alberta's conventional oil and gas industry. Brine contains high concentrations of sodium chloride which, when released in soils, causes negative effects on soil properties and plant growth. Impacts of brine contamination are long lasting, with the loss of vegetative cover leading to soil erosion on brine affected sites. To date, brine remediation in soil relies on soil washing, which requires large volumes of water and ultimately transfers brine residuals to local watersheds. Recently work by Klaustermeier et al. (2017) highlights a novel method to remediate brine spills by promoting salt efflorescence at the soil surface using crystalline inhibitors. However, the methodology appears to be less effective in finer soil textures. Here we highlight early stage work which attempts to increase the ability of crystalline inhibitors to remove brine from finer textured soils.

Preferred Platform: Poster Presentation

Student Presenter: n

Nitrogen mineralization during incubation of heavy clay soil amended with pelletized poultry manure

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Pelletized hen manure, a product of poultry farms, is a valuable fertilizer. However, its contribution to soil nitrogen fertility in heavy clay soils for cereal production during a short growing season is very poorly understood. Valorizing pelletized hen manure as a nitrogen fertilizer for northern agriculture requires information on the pattern of nitrogen release after pelletized hen manure is applied to the field. The objective of this study was to determine nitrogen mineralization rate of pelletized poultry manure in a controlled laboratory study. Pelletized hen manure from a commercial poultry facility was mixed with heavy clay soil, moisture content adjusted to 75% of field capacity, and incubated at 10°C or 25°C for 10 weeks. The N input from pelletized hen manure was 0, 30, 60, 90, 120, 180 and 240 kg N/ha. As expected, there was significantly more mineral N ($\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$) released from pelletized hen manure with higher N input rates. However, mineral N concentrations were lower at the higher incubation temperature, possibly due to volatilization. Rapid urea hydrolysis observed in this study implies a potential N loss through ammonia volatilization when pelletized hen manure is broadcast on the soil surface. Methods to assess the N fertilizer value of pelletized hen manure in current and future growing seasons will be discussed.

Preferred Platform: Poster Presentation

Student Presenter: N

Mechanisms affecting the adsorption of β -N-methylamino-L-alanine (BMAA) in organic and mineral soils

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β -N-methylamino-L-alanine (BMAA) is a non-proteinogenic amino acid that is produced by diverse cyanobacteria taxa and acts as a cyanotoxin. As the causative agent of neurodegenerative diseases in mammals, BMAA concentrations in the environment are an emerging public health concern. Cyanobacteria blooms that are discharged directly into croplands, irrigation canals, and forest land without treatment may be an ecological hazard and human health risk. However, the transformations and fate of BMAA in the soil ecosystem is poorly understood because there are only a few papers in the literature that report the concerns of in soil ecosystems. The presence of variable charged amino acids in the BMAA molecule may promote its adsorption to reactive soil surfaces (e.g., exchange sites on minerals, organic matter, and organo-mineral surfaces). The objective of this study is to investigate mechanisms influencing the adsorption of BMAA on soils with different surface reactivity, under variable soil pH conditions. Soils with different surface reactivity will include (1) field soils and (2) artificial soil composed of organic matter alone, kaolinite clay alone and Fe/Al oxides. Batch equilibrium experiment will be used to study adsorption isotherms and kinetics of BMAA under three pH conditions – pH 6.0, 8.0 and 9.0. This includes values that are below, close to and above the isoelectric constant of BMAA ($pK_a = 7.9$). The BMAA concentration will be determined by LC-MS/MS. Results will be used to interpret the relationship between BMAA adsorption and surface reactivity in soils, and to elucidate the mechanisms, including cation exchange, proton transfer and physical adsorption, that are responsible for BMAA adsorption in soil. This study will elaborate adsorption properties of BMAA in the soil and will lay a foundation for further research on BMAA in soil ecosystems.

Preferred Platform: Poster Presentation

Student Presenter: Y

Introductory Soils Courses: A Frontier of Soil Science Education in Canada

Maja Krzic, Thomas T. Yates, Nathan Basiliko, Maxime C. Pare, Amanda Diochon, Mathew Swallow

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As the focus of soil science education in Canada and elsewhere has shifted towards non-soil science majors, it is important to understand if and how this has affected the scope of introductory soil science courses. The objectives of this study were to inventory Canadian postsecondary units that offer introductory soil science courses and to document attributes of instructors, students, and teaching approaches in these courses. We surveyed 58% of the instructors of introductory soil science courses across Canada, and most of these courses were offered by geography and environmental science units. The majority of instructors followed a traditional lecture (86%) and laboratory (76%) delivery format, while 36% used online teaching resources. Introductory courses were delivered by primarily one instructor, who held a PhD in a tenure track position and in most cases developed the course themselves. Over half of the instructors surveyed used either a required or a recommended textbook; pointing to the need for creation of a Canadian-authored soil science textbook. Several follow-up studies are needed to evaluate teaching methods used in the upper level soil science courses, student's perceptions of teaching in soil science, and instructors' knowledge of resources available for online and/or blended learning.

Preferred Platform: Oral Presentation

Student Presenter: N

What are the field skills and knowledge essential for professional practice? – Results from a survey of soil professionals

Tom Yates, Chi Chen, Hugh Hamilton, Maja Krzic, Sylvie Quideau, Kyle Hodgson, Kevin Keys, Jim Warren, Adrian Unc, David Kroetsch

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The Canadian Society of Soil Science (CSSS) intends to develop and deliver a summer field school for students, professionals, and other persons interested in pedological knowledge and field skills. It is expected that this learning opportunity will be first offered during the CSSS Annual Meeting in the summer of 2019 at the University of Saskatchewan. To ensure that the design of the field school captures learning outcomes and course material essential not only academically, but also professionally, a survey of soil professionals working for government, industry, and non-governmental organizations was conducted. The purpose of the survey was to find out what supervisors and employers of our graduates view as essential field skills and knowledge in soil science. What are they looking for when they hire professionals to work in the field? What does the professional soil science community want in terms of ongoing or advanced training? Is there a need for a national soil science educational resource to enhance learning and continuing education for both academics and professionals? Is there a desire and need to have certification of field pedology skills? A ten-member team, representing soil science professionals from industry and government, and soil science academics, developed and delivered a 14-question electronic survey through the Social Science Research Laboratory at the University of Saskatchewan. Professionals and managers from across Canada who recruit, supervise, or work directly with soil professionals were invited to participate. This presentation will report the results of the survey.

Preferred Platform: Oral Presentation

Student Presenter: N

Spatial-temporal relationship of variable nitrogen fertilization rates to ‘hot moments’ and ‘hot spots’ of nitrous oxide fluxes in *Panicum virgatum* L.

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Nitrogen (N) fertilizer is essential to maintain agricultural yields, but is susceptible to reactions that produce nitrous oxide (N₂O), which acts as a greenhouse gas and contributes to stratospheric ozone depletion. It is difficult to predict where these reactions will produce ‘hot spots’ of high N₂O fluxes in a field, as well as the ‘hot moments’ when peak N₂O fluxes occur. The objective of this study is to relate the N₂O fluxes in a switchgrass (*Panicum virgatum* L.) field to N fertilizer application rates of 0, 50, 100, and 150 kg N/ha while considering the spatial-temporal heterogeneity of the field. In summer 2017, soil samples were collected at 128 locations in an 8.87 ha switchgrass field in the Cookshire-Eaton region (45°20'N, 71°46'O) of Québec Canada. The sandy loam soil was analysed for static parameters: macro- and micro-nutrient content, electrical conductivity, pH and texture composition. The spatial soil map of the field was generated with R 3.4.1 statistical software and ArcGIS. In spring 2018, each N fertilizer rate was applied in 3 replicate blocks (20 m wide x 80 m long). Non-flow-through non-steady-state chambers were installed (n=3 per block) for manual gas sampling and N₂O fluxes were calculated during a 1 h period every 7-10 d during the growing season. Geospatial characterization of agricultural fields and precision agriculture techniques may improve predictions of the spatial-temporal variation in N₂O fluxes resulting from N fertilizers, and will be discussed at the project completion in the context of improving climate-smart agriculture. The preliminary occurrence of ‘hot spots’ and ‘hot moments’ of N₂O flux was interpreted relative to the fluctuations in dynamic parameters and the underlying field heterogeneity. A review of existing literature was completed to generate predictions of locations and times expected to have increased rates of N₂O production.

Preferred Platform: Oral Presentation

Student Presenter: Y

Soil and Crop Response to Foliar Phosphorus Application

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In Saskatchewan, rates of phosphorus fertilizer have been increasing to meet higher yield potentials as well as balance the phosphorus removed in harvested material. Most of this fertilizer is placed with or near the seed. However crops such as canola or pea are sensitive to injury from to higher rates of seed-row placed fertilizer. Soil applied phosphorus fertilizer is also susceptible to adsorption and precipitation reactions, reducing availability. A two year study began in 2016 to evaluate the effect of foliar P application on pea, wheat and canola crop response in contrasting Saskatchewan soils: Brown, Dark Brown and Black Chernozems. Prior to seeding, site soils were characterized for MK-extractable P. The soil at the Black Chernozem site had lowest extractable P (7 mg P kg⁻¹), followed by the Brown soil (11 mg P kg⁻¹) and the Dark Brown so The foliar P source used was mono-potassium phosphate dissolved in water. The greatest grain and straw yield response to P fertilization treatment was observed in canola in the Black soil. As the proportion of P applied in foliar form increased, the yield response diminished. Overall, pea did not respond to P fertilizer treatment across all sites and wheat responded to only seed-placed MAP. In the P deficient Black soil (10 mg P kg⁻¹), canola appeared to have the greatest capacity for P uptake through leaf tissue, however it was not enough to consider foliar P fertilization as a substitute for conventional seed-placed MAP.

Preferred Platform: Oral Presentation

Student Presenter: Y

**Evaluating the Potential of SMOS Soil Moisture Observations for Seasonal Yield
Forecasting of Canola across the Canadian Prairies**

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As climate variability intensifies and the global demand for food increases, there exists a growing need to improve the accuracy and robustness of crop yield forecasting systems. Satellite remote sensing offers several benefits over traditional, ground-based methods for forecasting crop yields, including greater spatial and temporal coverage, reduced costs, and the elimination of human-related biases and errors. However, the wide-spread use of vegetation indices in many forecasting models, including the Integrated Canadian Crop Yield Forecaster (ICCYF) developed by Agriculture and Agri-Food Canada (AAFC), presents several challenges due to the reliance on visible and near-infrared portions of the electromagnetic spectrum. Recent developments in satellite soil moisture platforms, such as the Soil Moisture Ocean Salinity Mission (SMOS) satellite, present a unique opportunity for yield forecasting as they allow for accurate, global observations of surface soil moisture at frequent temporal resolutions using microwave radiation. In this study, agroclimate variables and normalized difference vegetation index data from the NOAA-AVHRR platform, along with SMOS weekly volumetric soil moisture data were used as inputs for forecasting canola yields across the Canadian Prairies from 2010 to 2016 with the ICCYF model. Top predictors were identified using robust variable-selection and forecasts were generated using Markov-Chain Monte Carlo algorithms and random forest-tree machine learning. Model performance was evaluated against township-level yield survey data provided by AAFC for the 2010-2016 period. Incorporating soil moisture as a key variable will provide a more accurate descriptor of crop stresses, allowing for improved yield forecasting which will have significant implications for the development of export-import policies, food security policies, and efficient land management practices.

Preferred Platform: Oral Presentation

Student Presenter: Y

Contributions of geophysical data and SAR data collected at C-band and L-band for estimation of field scale soil moisture

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An issue with passive microwave estimates of soil moisture is the large footprint of the available products; typically larger than 10x10 Km. Research has described successes in downscaling this data to higher resolution using optical approaches, high resolution modeling and observation based approaches using Synthetic Aperture RADAR (SAR) sensors such as RADARSAT-2. The C-band SAR based studies have shown strong sensitivity to soil moisture under bare soils but also have significant sensitivity to vegetation canopy and surface roughness. Recent reviews of the soil moisture downscaling literature, suggest the development of approaches that combine data from multiple sources including remote sensing (including SARs), geophysical models, and other geophysical information such as topography, soil type/texture, vegetation/land cover type and greenness fraction. Here we use a Random Forest (RF) based model to estimate soil moisture variability at high resolution (~100x100m). Within the RF regression approach we upload several geophysical data sets (soils, topographic information) and L- and C- band SAR data to make soil moisture high resolution soil moisture estimates. In this study we evaluate the retrievals of soil moisture and contributions of the geophysical and the SAR data for the soil moisture estimates. In our simulations completed near Carman Manitoba Canada, the geophysical data (particularly soils and topography explain the most variance for the high-resolution soil moisture estimates.

Preferred Platform: Poster Presentation

Student Presenter: Y

Quantifying surficial crop residue using a supervised classification method and multispectral drone imagery

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Crop residues on the surficial layer of the soil are important to quantify for understanding nutrient cycling. Through improved quantification of residue, the amount of carbon returning to the soil can be estimated more accurately. Multispectral drone imagery can be used for the detection of crop residue on the surface layer of soils. The purpose of this study is to create a supervised classification approach and associated open source GIS tool box to quantify crop residue on the soil using multispectral imagery collected using Uninhabited Aerial Vehicles (UAVs). The images used in this study were captured at the Elora Research Station (Elora, ON) in April 2017 using a Tetracam RGB + 3 (400-700nm, 680nm, 700nm, and 800nm) mounted on a DJI Matrice 100 drone unit. The field site is a long-term trial plot, with 30 unique trials that employ different land management practices (including conventional tillage to no till). In addition to the camera data, overhead photos were obtained over each of the field trials using a camera. A manual grid-based residue counting procedure on the photos was conducted to compare with the supervised classification approach based on the UAV collected multispectral data. A principal component analysis and Dunn Sidak correction was performed on the 6 camera bands of the multi-spectral instrument, suggesting that all bands were significant for the differentiation approach. Correlations estimated among the residue estimates obtained from the multispectral UAV imagery and manual residue counts, based on analysis of the overhead photos, are significant. The residue classification code, implemented into Whitebox GAT, is available as a downloadable tool to improve the speed of residue classification.

Preferred Platform: Poster Presentation

Student Presenter: Y

The agromineral Spanish River Carbonatite: an alternative to chemical fertilizers?

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Soils are a crucial resource in agroecosystems, providing food, habitats and a medium for biogeochemical processes. As such, they should be protected; yet they have become degraded with the misuse of chemical fertilizers (Nitrogen-Phosphorous-Potassium, NPK), which have adverse effects on the environment. Spanish River Carbonatite (SRC) is an agromineral rich in nutrients which may serve as an NPK alternative. The goal of our study was to determine the impact of SRC and NPK on microbial abundance and activity in controlled conditions and in vineyard plots. We hypothesized that SRC would stimulate microbial communities because of its varied composition. We had three treatments: no amendment (control), SRC, and NPK (20-20-20). Soil samples were taken from the rhizosphere of cover crops grown either in pots (before planting and 56 days after planting) or between vine rows (early spring and late summer). Colony-forming units grown on specific media were counted and soil respiration was assessed. SRC was shown to stimulate soil microbial communities in the vineyards but not in the greenhouse pots. Legumes grown in pots amended with SRC had significantly more nodules and higher soil pH than pots treated with NPK. However, soil from pots treated with NPK exhibited higher microbial activity than pots treated with SRC. Thus, the beneficial effects of SRC on microorganisms seen in the vineyards were not observed in the greenhouse. We propose that the impact of SRC and fertilizer on microbial communities is dependent on the type of soil they are being applied to.

Platform: Poster Presentation

Student Presenter:

Developing Pulp & Paper Mill Residuals for Land Application

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Pulp and paper mills generate large quantities of both organic and mineral residual products from both energy and chemical recovery processes and the treatment of wastewater. Disposal of these waste products represents a substantial portion of the operational costs for mills, and disposal methods typically involve landfilling or incinerating materials. The objective of this project is to develop pulp mill residuals as soil reclamation amendments across a range of management regimes: agricultural, forestry and mining impacted landscapes. A growth-chamber mesocosm experiment was used to evaluate 5 different soils or mine tailings substrates, mixed with one of 3 pulp and paper biosolids; each from mills with different pulping and wastewater treatment processes at application rates of 20 or 40 t/ha. Pots were seeded with annual ryegrass or white clover and controls of pure soil/tailings and pure sludge were also included. After planting, trays were placed in a plant growth chamber for 5 weeks on a diurnal cycle with temperature and watering matching idealized long-term average July climate conditions in Sudbury Ontario. After 5 weeks; germination rate was monitored and plants in each was harvested with above and belowground biomass separated, dried, and weighed. There was a significant improvement in both germination rate and biomass with the addition of all pulp and paper bio solids to all soil or tailings types ranging from a productive circumneutral-pH and medium-textured agricultural soil to coarse-textured acidic silvicultural pine forest soils, to heavily S and metal polluted upland soils from downtown Sudbury, to a Ni-Cu mine tailing. Additional information is being collected on soil mixture and plant tissue concentrations, and mixtures of pulp and paper sludges plus mineral residuals (like wood ash and waste lime mud) are being tested in a new trial. However our preliminary conclusion is that pulp and paper biosolids from a variety of mills can improve soil nutrition across a broad range of soil (and mine tailings) conditions in Northeastern Ontario.

Platform: Poster Presentation

Student: Yes

ESSSA_01: Understanding earthquake ground motion at sites in Central and Eastern North America

Conveners: Samantha Palmer¹, Alan Yong²

Co-chairs: Samantha Palmer¹, Alan Yong²

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3D linear and nonlinear ground motion simulation for the Kinburn basin

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The 3D staggered-grid finite difference scheme (AWP-ODC program) has been used to model linear and nonlinear ground motion for the Kinburn basin in Ottawa, Canada, with a very high (~20) shear-wave impedance contrast between bedrock and soil in comparison to typical impedance contrasts of 3–5 in many other places. The nonlinear behavior of soil has been modeled using Cyclic nonlinear models which determine the nonlinear stress-strain behavior of soil by following the actual stress-strain path during cyclic loading. In regular linear simulations, the shear modulus of an element in the model is assumed to be constant in the stress-strain relation. In the proposed method, the shear modulus is modified according to the strain level that should be calculated for each time and each element in the model. Detailed geophysical information was used to model the study basin and modulus reduction equation. The focal mechanism associated with the M4.6 Ladysmith earthquake recorded on May 17th, 2013 was used as the source while the magnitude was scaled to 7.5 to study the effects of nonlinearity. In this simulation, the linear and nonlinear viscoelastic ground motions were carried out in the frequency range of 0-1 Hz. The simulations prove the role of depth and shape of the basin and the importance of nonlinear effects in an accurate ground motion simulation.

Preferred Platform: Oral Presentation

Student Presenter: Y

Shear Wave Velocity of Quaternary Units and VS30 Mapping in Charleston, South Carolina

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As part of the Charleston Area Earthquake Hazard Mapping Project (CAEHMP), we have compiled a dataset of 277 borehole and geophysical measurements of shear wave velocity (VS) of Quaternary units in the Charleston region, building upon previous work by Mohanan et al (2006) and Fairbanks (2006). The Quaternary geology at each site has been updated to the most recent surficial geology map of the region (Weems et al., 2014). The average VS of these units range from ~140 m/sec up to ~220 m/sec and their maximum thickness ranges from 7 to 26 meters. In general, VS increases with age, being lowest for man-made (artificial fill and phosphate mine spoil) and Holocene tidal marsh sites (140-160 m/sec) and increasing gradual up to the middle Pleistocene Ladson Formation (224 m/sec). Unexpectedly, VS decreases to slightly below ~180 m/sec in the early Pleistocene Penholoway Formation. In late Pleistocene and younger units VS clearly increases with depth (typically 2-4 m/sec per meter); in older units it is either unchanged (1 m/sec per meter) or even decreases with depth (Ladson Formation). By combining the VS of Quaternary units together with maps of Quaternary sediment thickness and the VS of the underlying Upper Cooper Group (VS = 431 m/sec), we can rapidly calculate first VS30 changes across the entire study region.

Preferred Platform: Oral Presentation

Student Presenter: N

Improved proxies for surface wave site response in central and eastern North America

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Because of low rates of local seismicity and low attenuation, regional-distance surface waves are responsible for the peak ground motions observed over many parts of central and eastern North America during periods of years to decades. Most attention has been paid to the shaking due to direct shear waves, however, because of the greater potential for damage from local events and the assumption that body waves dominate the resonant frequencies of most buildings. The effects of shallow structure on the amplitudes of surface and body waves—and their frequency dependences—can differ substantially. Here, a new model of Lg attenuation focused on the central and eastern U.S. (CEUS) constrains surface-wave site-response at frequencies from 0.5 to 16 Hz, and this model is used in order to investigate the utility of several topographic, geologic, and geophysical proxies for amplification/damping of surface waves. Among local topographic slope, km-scale relief, passive-source H/V estimates of depth to bedrock, crustal thickness, and interpolated surface heatflow, km-scale relief is the most effective proxy. Notably, topographic relief over lengthscales of several km achieves nearly 3 times the variance reduction of local topographic slope, a proxy that has been extensively tested for local body waves in tectonically active areas (41% vs. 14%), and this improvement is roughly consistent across frequencies. These findings suggest that GMPEs for surface wave ground motions, at least in the CEUS, should be addressed differently from local body waves.

Preferred Platform: Oral Presentation

Student Presenter: N

ESSSA_01

Site conditions and kappa in Eastern Canada

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The characterization of high-frequency (10 Hz) ground motions for rock sites in Eastern North America is a critical seismic response issue for major infrastructure, particularly nuclear power plants. Canadian nuclear plants are sited on rock of varying characteristics and may thus have varying high-frequency decay characteristics. We aim to examine kappa, a measure of the slope of amplitude decay at high frequencies in the spectral domain (Anderson and Hough, 1984), for site conditions including a range of rock and soil types. We measure kappa at seismic stations in Eastern Canada from Ontario to New Brunswick, using earthquake recordings of M3 within 150 km of a seismic station. We also characterize site conditions at the stations, using microtremor data. Kappa values are compared to site conditions to gain insight into the relationship between kappa and physical rock/soil properties.

Preferred Platform: Oral Presentation

Student Presenter: Y

Imaging and characterizing shallow sedimentary strata using teleseismic arrivals recorded on linear arrays: An example from the Atlantic Coastal Plain

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Unconsolidated, near-surface sediments can influence the amplitudes and frequencies of ground shaking during earthquakes. Ideally these effects are accounted for when determining ground motion prediction equations and in hazard estimates summarized in seismic hazard maps. This study explores the use of teleseismic arrivals recorded on linear receiver arrays to estimate the seismic velocities, the frequencies of fundamental resonance peaks, and to image major reflectors in the Atlantic Coastal Plain (ACP) and Mississippi Embayment (ME) strata of the central and southeastern United States. These strata have thicknesses as great as 2 km near the coast in the study areas, but become thin and eventually pinch out landward. Spectral ratios relative to bedrock sites were computed from teleseismic arrivals recorded on linear arrays deployed across the sedimentary sequences. The large contrast in properties at the bedrock surface produces strong resonance peaks in the 0.2 to 4 Hz range. Sediment thicknesses derived from drill hole data allow for estimation of average velocities versus depth by predicting the observed frequencies of resonance peaks. The sloping bedrock surface allows for calculation of a depth-varying velocity profile, under a flat-layer assumption. The spectral ratios can then be converted from frequency to depth, resulting in an image of the subsurface similar to that of a seismic reflection profile with amplitudes being the spectral ratio caused by a reflector at that depth. The complete data set thus provides an average velocity function for the sedimentary sequence, the frequencies and amplitudes of the major resonance peaks, and a subsurface image of the major reflectors producing resonance peaks. The method is demonstrated using three receiver arrays crossing the ACP and ME strata that originally were deployed for imaging the crust and mantle, confirming that teleseismic signals can be used to characterize sedimentary strata in the upper km.

Preferred Platform: Oral Presentation

Student Presenter: N

Peak Frequency as a Site-Effects indicator in Central and Eastern North America and California

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In this study we explore the applicability of f_{peak} (the peak frequency of the site response transfer function) as a site-effect parameter for sites in central and eastern North America (CENA) and California. This is done by analyzing the residuals calculated from ground-motion amplitude data with respect to a selected regional ground-motion prediction equation (GMPE). For each region, an amplification model is developed that explains the residuals in terms of f_{peak} time-averaged shear-wave velocity in the upper 30 m (VS30). For CENA, we show that the estimated frequency-dependent VS30 scaling term is similar in form to that obtained in previous studies for sites in California. However, the scaling term is less significant in amplitude for CENA in comparison to that for California, suggesting that VS30 is not as strongly indicative of site response. By using f_{peak} as the primary site-effects modeling parameter, we remove most of the VS30 scaling effects that are implied by the data. Finally, we provide recommendations on the effective use of f_{peak} and VS30 to model site effects in CENA, differentiating between glaciated and non-glaciated sites. Glaciated sites show larger amplifications compared to non-glaciated sites, especially at intermediate-to-high frequencies, presumably due to the strong impedance contrast at the base of glaciated sites. Following the same methodology for California, we show that f_{peak} is also an indicative site-effects variable in California. Incorporating f_{peak} as an additional site parameter, we can reduce the site-to-site variability component of ground motion (by 5% on average). We conclude that including f_{peak} as an additional site response variable is warranted in California, in addition to its applicability for sites in CENA.

Preferred Platform: Oral Presentation

Student Presenter: y

ESSSA_03: Historic and Prehistoric Earthquakes in Central and Eastern North America

Conveners: John E. Ebel¹ and Martitia P. Tuttle²

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Deformed river terraces and coseismic sackungen near the Reelfoot Fault in the New Madrid Seismic Zone, USA

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Jessica T Jobe

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The Reelfoot fault is a NNW-SSE oriented thrust fault in the New Madrid Seismic Zone and is capable of producing large (M7) earthquakes such as the events in 1811-1812. We use 0.5- and 1-m-resolution aerial lidar data to identify possible tectonic surface deformation near the southern Reelfoot fault across the lower Obion River, a west-flowing tributary of the Mississippi River in western Tennessee. Here, the Reelfoot fault projection coincides with pronounced Obion valley narrowing and a concentration of elevated terrace remnants at the intersection of the Obion and Mississippi valleys, which could reflect downstream Obion River uplift. One of the elevated terraces, the Finley terrace, records ~2 m of apparent back-tilting over ~200 m distance since ~25ka. A fault-related interpretation of these geomorphic indicators, along with a history of Obion valley damming, is consistent with blind west-side-up reverse motion. We plan to compare preliminary stratigraphic observations from a hand auger profile along the Finley terrace to previous coring elsewhere in the valley and the lidar-derived profiles. North and south of the Obion River valley, lidar-derived digital elevation models along ~170 km of the Chickasaw bluffs reveal a series of nested grabens and ground cracks that we interpret as sackungen (gravitational ridgetop spreading features). We find that sackungen are only present close (15 km) to the Reelfoot fault despite nearly homogenous regional bluff geology and relief. Additionally, sackungen appear preferentially oriented parallel and normal to nearby fault trends. We interpret these relationships to indicate that the sackungen record earthquakes on nearby faults, consistent with a companion trenching study of one of these sackungen. The Obion River geomorphology investigation and sackungen mapping present new opportunities to expand the paleoseismic record and quantify possible displacement and rupture length potential on the southern Reelfoot fault.

Preferred Platform: Oral Presentation

Student Presenter: N

ESSSA_03

**A NEW EVALUATION OF THE LOCATION OF THE MARCH 21, 1904 MLg5.7
EARTHQUAKE IN EASTERN MAINE**

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An earthquake on March 21, 1904 with estimated MLg 5.7 was most strongly felt in the coastal towns of eastern Maine and southern New Brunswick. In a paper in BSSA in 1911, Harry Fielding Reid estimated an epicenter about 30 km west Passamaquoddy Bay based on an isoseismal map that he compiled. N. A. Heck and R. A. Eppley in the 1958 edition of U.S. Earthquakes put the event location about 20 km east of Reid's epicenter and thus close to Passamaquoddy Bay. In this analysis a new epicenter for the 1904 earthquake is proposed based on a reevaluation of the written reports of the earthquake and its aftershocks. At least minor damage due to the mainshock was reported from East Rumford, ME on the west to St. John, NB on the east, with more substantial reports of damage from Eastport and Ellsworth in Maine and St. Stephen and St. John in New Brunswick. Most communities in Maine and New Brunswick felt two or three aftershocks within about 10 minutes after the mainshock. West Gouldsboro, ME reported more than 14 aftershocks that lasted two days, and Bar Harbor, ME indicated at least 7 aftershocks were felt there. Sullivan Harbor, ME also reported feeling a number of aftershocks. Descriptions of the mainshock sounds are a rumbling noise at farther distances from and a loud rumble or heavy thunder at closer distances to the epicenter. At Bar Harbor, ME the earthquake sounded like a terrific explosion, accompanied by crackling and groaning noises. Observers at Sullivan Harbor also indicated that the earthquake sounded like an explosion. The epicenter of this earthquake was likely in Maine somewhere near Sullivan Harbor and West Gouldsboro and across Frenchman Bay from Bar Harbor. This new estimate for the location of the 1904 earthquake is about 40 km southwest Reid's epicenter and about 50 km from the epicenter of Heck and Eppley. From this new analysis, the epicenter of the 1904 earthquake was not in the area of Passamaquoddy Bay, as previously thought.

Preferred Platform: Oral Presentation

Student Presenter: N

**Preliminary results from a paleoseismic investigation of sackungen near the Reelfoot fault,
New Madrid Seismic Zone, USA**

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Sackungen are gravitational spreading features that can form as a result of strong ground motion associated with earthquakes. We document ground cracks related to ridge-top spreading, interpreted as sackungen, along the bluffs of the eastern margin of the Mississippi River floodplain. The sackungen are concentrated within 15 km of the southeast-dipping Reelfoot reverse fault and we hypothesize that they formed in response to shaking associated with earthquakes on the Reelfoot fault. To test this hypothesis, we excavated a paleoseismic trench across sackungen at the Paw Paw site. In the trench exposure, we identified four packages of scarp-derived colluvial sediment that postdate 30-13 ka Peoria loess. We interpret the colluvial packages to have been deposited following episodic reactivation of the sackungen. Radiocarbon and luminescence dating, along with Pb-Cs analyses, constrain the ages of the colluvial packages, which overlap with previously documented earthquakes, including the historical earthquakes in 1811-1812 AD, and three prehistoric events at ~1450 AD, ~900 AD, and ~2350 BC documented through a combination of paleoseismic trenching and paleoliquefaction investigations. Episodic deposition and sample ages support a coseismic origin of the sackungen. If the sackungen have recorded all major earthquakes associated with the Reelfoot fault, then only four earthquakes have occurred along this fault since deposition of the Peoria Loess (since ~13 ka). Importantly, this result suggests an irregular pattern of earthquake recurrence, with only a single early-to-mid Holocene earthquake. In contrast, the most recent millennium has been punctuated by an episode of clustered, major seismic events. This investigation demonstrates the utility of constraining earthquake timing using seismically triggered sackung features.

Preferred Platform: Oral Presentation

Student Presenter: N

Ongoing Geomorphic, Geophysical, and Paleoseismic Investigations of the Big Creek Fault Zone, Phillips County, Arkansas

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The approximately 50-km-long, Big Creek fault zone (BCFZ) in east-central Arkansas is defined by a series of northeast-trending escarpments and tonal lineaments. It was first recognized over 70 years ago by Fisk (1944) yet the fault zone remains poorly characterized. Our recent and ongoing investigations include seismic reflection surveys, geomorphic mapping, and paleoseismic studies that collectively provide new insights and raise new questions regarding the nature and origin of the BCFZ. The 6-km-wide BCFZ is comprised of two primary elements: (1) the Big Creek escarpment, and (2) Kingtown lineament. Late Quaternary geomorphic features suggestive of tectonic deformation along the BCFZ include NW-side-up linear escarpments, aligned drainages, and persistent tonal lineaments. Our previous investigation at Pigtail Point along the Big Creek escarpment documented liquefaction-related deformation, faults and folds interpreted from seismic reflection surveys, and low amplitude folding interpreted from paleoseismic excavations in late Pleistocene deposits. These observations collectively suggest the presence of faulting at depth. In-progress investigations of the Kingtown lineament include LiDAR analysis and multiple planned seismic reflection surveys and trenches. Geomorphic analysis of Kingtown lineament shows the alignment of sharp linear tonal contrasts, discrete 0.5- to 2-m-high escarpments, and deflected drainages that are laterally persistent for several kilometers. An initial seismic survey indicates truncated reflectors at depth. Ongoing geomorphic analyses using the recently available Mississippi Embayment LiDAR indicates that some of the features originally thought to be tectonic may in fact be fluvial in origin. These observations highlight the challenges of working in apparently low-slip-rate environments with relatively young deposits, and the need to utilize multiple investigative techniques to evaluate geomorphic features and near-surface structures.

Preferred Platform: Oral Presentation

Student Presenter: N

**Felt reports from the Dominion of Newfoundland, Canada and Saint-Pierre and Miquelon
for the 1929 Magnitude 7.2 Grand Banks earthquake**

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The 18 November 1929 Magnitude (M) 7.2 earthquake is the largest historical earthquake of eastern Canada. The earthquake was felt over most of Newfoundland and Labrador, at St-Pierre and Miquelon, in the Maritimes, eastern Quebec and New England. Shortly after the earthquake, macroseismic questionnaires were posted by seismologists of the Dominion Observatory of Canada to municipalities in eastern Canada and in the Dominion of Newfoundland. A similar effort was done in the United States but we did not include them in our study. Together with other felt information gathered from other sources such as newspapers, we ended up with some 151 felt reports, including one from St-Pierre and Miquelon. We digitally scanned all materials that existed from these areas. For each locality, the felt information was rated on the Modified Mercalli intensity (MMI) scale, together with its location and supporting evidence for the MMI rating. The information was tabulated in a Microsoft Excel sheet. The material is available as a GSC Open File Report, a process that took a total of about four weeks. We hope that similar macroseismic information for other Canadian earthquakes be included in a forthcoming intensity database.

Preferred Platform: Oral Presentation

Student Presenter: N

What We don't know about the New Madrid Earthquakes, A Historians Perspective

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The 1811-1812 New Madrid earthquakes were seismic events experienced across a wide swath of the eastern and southern United States and adjacent regions of Canada. They have been studied using the historic record accorded by newspaper accounts to find felt reports in the far field. Other historic records have been consulted to further complete this body of information. This research effort still leaves much information undiscovered. One ongoing project is exemplified by the New Madrid Compendium newspaper research project, which discovers, examines, and catalogs new felt reports for all three major New Madrid earthquakes and their aftershocks. In previous presentations new and revised felt reports have been documented for the December 16, 1811 and January 23, 1812 earthquakes. This poster is a representation of the gaps still existing in our knowledge of the New Madrid earthquakes that new research might uncover. The use of historic data to help map the effect of the New Madrid earthquakes in the far field was pioneered by Street and Nuttli in 1984. However, a review of the data and additional research has shown more can be done to and better define the New Madrid earthquakes. New information can help in reducing the uncertainty about felt report information in many of these locations. Other gaps in our knowledge of the earthquakes such as changes in terrain caused by them and extent of damage to the region still can be further explored. This poster will highlight some of the more interesting gaps in our knowledge from the perspective of the historic record for the earthquakes.

Preferred Platform: Poster Presentation

Student Presenter: n

**The Paleoearthquake Record between the New Madrid and Wabash Valley Seismic Zones
in the Central United States**

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Earthquake-induced liquefaction features, small- and moderate-size sand dikes, were found during survey of ~110 km of selected portions of the Cumberland River in northwestern KY, as well as the Middle Forks of the Saline River and Skillet Fork in southeastern IL. Radiocarbon and optically-stimulated luminescence dating as well as liquefaction potential analysis were used in this study. Along the Cumberland River, sand dikes were very weathered, exhibiting fines accumulation, iron staining and cementation, and likely formed since 7250 yr B.P. These dikes may well have formed during the M~7.3 Vincennes earthquake in 5900-6300 yr B.P. in the Wabash Valley seismic zone (WVSZ). A younger generation of dikes along the Cumberland crosscut older dikes, was less weathered, and likely postdates the Vincennes earthquake. A New Madrid seismic zone (NMSZ) event in 4150-4450 yr B.P. might have been responsible for these liquefaction features as well as others along the nearby Tennessee River and Cache River in southern IL. Along the Middle Fork of the Saline River, dikes were slightly weathered and formed between 330-1225 yr B.P. These dikes may have formed during the NMSZ events in 900-1200 yr B.P. and 350-650 yr B.P. Most of the dikes along Skillet Fork were weathered, exhibiting fines accumulation and iron staining, and formed between 2010-2715 yr B.P. The ages of these features overlap with that of a sand blow in the NMSZ that formed between 2180-3380 yr B.P. A couple of unweathered dikes likely formed more recently. It is possible, but not required, that NMSZ events were responsible for the formation of the Skillet Fork features. Our initial findings suggest that older sand dikes along the Cumberland River likely formed during the Vincennes earthquake in the WVSZ; whereas, younger dikes along the Cumberland, as well as other dikes along the Middle Fork of the Saline River and Skillet Fork, may have formed during Late Holocene earthquakes in the NMSZ.

Preferred Platform: Poster Presentation

Student Presenter: N

ESSSA_06: From Source to Site

Acting Convener: Oliver Boyd¹

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Seismic and Liquefaction Hazard Maps for Lake County, Northwestern Tennessee

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A five-year seismic and liquefaction hazard mapping project for five western Tennessee counties began in 2017 under a Disaster Resilience Competition grant from the U.S. Department of Housing and Urban Development to the State of Tennessee. The project supports natural hazard mitigation efforts in these five counties. The seismic hazard maps for Lake County in northwestern Tennessee are being completed in early 2018. Additional geological, geotechnical, and geophysical information has been gathered in Lake Co. to improve the base northern Mississippi Embayment hazard maps of Dhar and Cramer (2017). Information gathered includes additional geological and geotechnical subsurface exploration logs, water table level data collection and measurements, new measurements of shallow and deep shear-wave velocity (Vs) profiles, and the compilation of existing Vs profiles in and around the county. Improvements are being made in the 3D geological model, water table model, the geotechnical liquefaction probability curves, and the Vs correlation with lithology model for Lake Co. Resulting improved soil response amplification distributions on a 0.5 km grid will be combined with the 2014 U.S. Geological Survey seismic hazard model (Petersen et al., 2014) sources and attenuation models to add the effect of local geology for Lake Co. Resulting products will be similar to the Memphis and Shelby County urban seismic hazard maps recently updated by Cramer et al. (2018). Preliminary seismic hazard maps at PGA and 1.0 s show a 50% decrease in hazard at short periods and a 10% increase at long periods compared with USGS NSHMP maps.

Preferred Platform: Oral Presentation

Student Presenter: N

Toward probabilistic declustering of CENA earthquakes

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In areas of sparse large-magnitude seismicity such as central and eastern North America (CENA), a crucial component of hazard mapping is to distinguish between earthquakes that are simply aftershocks of prior events and those that represent ongoing strain accrual. Nevertheless, there is substantial debate and appreciable uncertainty surrounding magnitudes of paleo-mainshocks, Omori decay parameters, completeness magnitude of aftershock catalogs, and frequency-magnitude scalings (e.g., Gutenberg-Richter relations and the use of Gutenberg-Richter vs. characteristic recurrence models). Using a hybrid logic-tree/Monte Carlo approach that samples from the panoply of defensible values, however, it is possible to achieve probabilistic estimates of the proportion of modern earthquakes that should be removed during declustering. This methodology is first illustrated in the Eastern Tennessee Seismic Zone, where it can be shown that—to 98.5% confidence—modern earthquakes are not simply aftershocks of a prehistoric event. By contrast, seismicity rates in the New Madrid Seismic Zone are possibly attributable to the 1811-1812 events (though other details of the earthquake sequences are not), with 7.6% probability. Since hazard analysis is inherently probabilistic, integrating random sampling of the relevant parameters during catalog declustering could make estimates of CENA hazard more robust.

Preferred Platform: Oral Presentation

Student Presenter: N

Constant Stress Drop Scaling in an Intraplate Seismic Zone in Eastern Canada

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The Charlevoix seismic zone (CSZ) along the St-Lawrence paleo-rift system is the most active seismic area in eastern Canada. Proper assessment of seismic hazard requires information from earthquake source properties. Therefore, we study source parameters of earthquakes ($M_N \leq 4.5$) reported in the CSZ between June 2012 and July 2017. We first relocate ~ 520 events using P and S differential travel-times refined with waveform cross-correlation. We then use the empirical Green's function (eGF) to remove common path effects and determine event corner frequencies for the estimation of static stress drop values. The quality eGFs are determined based on proximity, travel-time differences, and waveform similarity. The low-frequency spectral amplitudes are used to determine the seismic moments of the main events. Static stress drops, source dimensions, and moment magnitudes are then determined assuming a circular crack model. Our relocation results highlight diffuse seismicity and cumulative moment contrast within and outside the impact structure that infers a highly fractured crustal volume, probably due to the Devonian meteorite impact. Stress drops range $\sim 3 - 200$ MPa with a median of 23 MPa, typical of an intraplate tectonic setting. Higher stress drop values are observed for events within the impact structure than the surrounding, which could be related to the contrast of fault maturity, although we have a limited number (39) of stress drop estimates. We observe constant stress drop scaling between $M \sim 2.2$ to $M \sim 3.2$. This extends the magnitude range of constant stress drops previously reported in the CSZ and indicates that rupture duration scales with moment in this intraplate seismic zone, similar to what have been inferred for interplate tectonic settings.

Preferred Platform: Poster Presentation

Student Presenter: Y

Non-invasive methods for determining the shear wave velocity profile at hard rock sites in Eastern Canada

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Theoretically, hard rock sites should exhibit no amplification but some amplification occurs at higher frequencies due to weathered/fractured “surficial” layers. We aim to expand and apply the multi-channel analysis of surface waves (MASW) and ambient vibration array (AVA) methodologies to sites in Eastern Canada which are of these site conditions. We collected MASW and AVA recordings in attempts to retrieve shear-wave velocity (V_s) depth profiles at multiple seismograph stations across Eastern Canada. Dispersion curves are calculated using frequency-wavenumber ($f-k$) and/or modified spatial autocorrelation (MSPAC) methods as well as horizontal-to-vertical-spectral ratios (HVSRS). Dispersion curves and HVSRS amplification functions are inverted to acquire V_s profiles for each site. We aim to acquire V_s profiles that capture the high frequency amplification of near-surface sediments or weathered/fractured rock layering above more competent bedrock below. Additional processing and interpretation is required for these stiffer sites in comparison to typical soft soil conditions in order to extract dispersion and/or amplification characteristics to invert for the subsurface site conditions. Preliminary results show that MASW captures the high frequency amplification of the near surface sediments more efficiently than AVA in order to acquire a V_s profile. This study will allow us to diversify and expand these non-invasive methodologies at more geologically complex sites.

Platform: Poster Presentation

Student: Yes

Building a USGS National Crustal Model: Theoretical foundation, inputs, and calibration

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Seismic hazard assessments depend on an accurate prediction of ground motion, which in turn depends on a base knowledge of three-dimensional variations in density, seismic velocity, and attenuation. We are building a National Crustal Model (NCM) starting with construction of a 5 layered 3-D geologic model, using Biot-Gassmann theory to couple geology and geophysical parameters, and applying several thousand local geophysical measurements for calibration. The calibration measurements include invasive and non-invasive estimates of shear- (S-) and compressional-wave (P-wave) velocity and density profiles. The calibration is primarily achieved by adjusting, in dependence on lithology, the pressure dependence of the theoretical foundation and two parameters controlling how porosity changes with depth. The crustal model is intended to be internally consistent and seamless on a national scale, but effort will be made to maximize consistency with state-level models by incorporating their data, methods, and underlying geologic model. An initial version of the NCM for the western U.S. defined on a 1-km grid is expected to be available in mid-2018 and for the remainder of the conterminous U.S. in 2019. An interactive web-enabled interface to the model will provide parameters needed for ground motion prediction equations in the western U.S., including, for example, the time-averaged shear-wave velocity in the upper 30 meters (VS30), and the depths to 1.0 and 2.5 km/s shear-wave velocity (Z1.0, and Z2.5). In addition, spatially variable frequency-dependent site amplification can be estimated from the NCM, and interpolated 3D models can be extracted for use with 3D numerical earthquake simulations. We also envision the NCM to be useful for earthquake source studies including better estimation of earthquake hypocentral location, moment, and stress drop, as well as to other Earth science disciplines more broadly.

Preferred Platform: Poster Presentation

Student Presenter: N

Adjustable Generic Ground-Motion Prediction Equation Based on Equivalent Point-Source Simulations: Accounting for Kappa Effects

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We modified the simulation-based generic ground-motion prediction equation (GMPE) model proposed by Yenier and Atkinson (2015) to enable adjustments for the near-surface attenuation parameter commonly referred to as kappa (κ_0). This enhances the usefulness of the model in applications over a broad range of site conditions from hard rock to soil. The new model is developed for magnitudes M3-9.6 and rupture distances up to 1000 km, for peak ground acceleration (PGA), peak ground velocity (PGV) and 5% damped pseudo spectral acceleration (PSA) at frequencies from 0.1 Hz to 100 Hz. The proposed κ_0 scaling term in the GMPE is a function of κ_0 , magnitude and stress parameter, and facilitates simultaneous inversion of response spectral amplitudes to estimate best-fit values of κ_0 for a specific site condition and region, along with best-fit values for event stress parameters and regional attenuation. We check the applicability of the modified generic GMPE to the empirical data in California. We determine an optimal κ_0 value of 0.04 s for the B/C boundary site condition (travel-time weighted average shear-wave velocity over the top 30 m $VS_{30} = 760$ m/s) for sites in California, through inversion of response spectral amplitudes from 1 to 20 Hz. The modified generic GMPE formulation provides a fully adjustable model that can be calibrated to the source, path and site conditions for any region of interest.

Preferred Platform: Poster Presentation

Student Presenter: y

The SCEC-USGS Dynamic Earthquake Rupture Code Verification Exercise

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Computational simulations of earthquake rupture provide clues for deciphering earthquake behavior. Whereas in a perfect world, we would have a complete set of observations at Earth's surface and at depth that would allow us to forgo simulations, in reality this is never the case, and additional tools are required to fill the gaps in our knowledge about how earthquakes work. Dynamic earthquake rupture simulation is one of the tools that is being used. This type of computational simulation is powerful, but it is also complex, so additional steps are required to ensure that it is working as expected. The SCEC-USGS Dynamic Rupture Code Comparison Group provides a solution. We have developed an extensive suite of benchmark exercises that are used to test computer codes aiming to simulate dynamic earthquake rupture and the resulting nearby ground motions. To date, more than a dozen codes have performed the exercises, demonstrating that they reliably produce similar results for fault rupture behavior and ground motions, when they use the same assumptions about fault geometry, initial stresses, crustal properties, and friction. Our website, scecddata.usc.edu/cvws, provides the details of our benchmark exercises and other information about our group's work. For more information, please see our new paper: Harris, R.A., M. Barall, B. Aagaard, S. Ma, D. Roten, K. Olsen, B. Duan, D. Liu, B. Luo, K. Bai, J.-P. Ampuero, Y. Kaneko, A.-A. Gabriel, K. Duru, T. Ulrich, S. Wollherr, Z. Shi, E. Dunham, S. Bydlon, Z. Zhang, X. Chen, S.N. Somala, C. Pelties, J. Tago, V.M. Cruz-Atienza, J. Kozdon, E. Daub, K. Aslam, Y. Kase, K. Withers, and L. Dalguer, A Suite of Exercises for Verifying Dynamic Earthquake Rupture Codes, *Seismological Research Letters*, 17 pages, 2018.

Preferred Platform: Oral Presentation

Student Presenter: N

Progress in developing seismicity catalogs and rate models for seismic hazard analysis

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The USGS makes earthquake catalogs for seismic hazard analysis by modifying and merging preexisting catalogs. Moment magnitudes are calculated, duplicates and non-tectonic events are flagged, and the catalog is declustered. The process involves ranking alternative size measures and overlapping input catalogs. Directly measured magnitudes are preferred over conversions, and the procedure recognizes that certain size measures are considered authoritative, for example, mbLg in the instrumental era in the central and eastern U.S. (CEUS). Duplicates are identified within time and distance windows that we develop by trial and error, and a hierarchy is used to select one favorite. For example, a catalog from a special study might be considered authoritative. Catalogs that list moment magnitudes directly generally get higher priority; compilations get lower priority. A uniform magnitude treatment is important in hazard analysis, so consistent rules are applied to estimate moment magnitudes and magnitude uncertainties, and to account for biases. For the CEUS, our catalog procedure closely follows that developed by the CEUS-SSC project (www.ceus-ssc.com, 2012). Statistics and completeness are analyzed to develop a recurrence model. Historical earthquakes are counted on a map grid, and the recurrence model is applied to estimate the rates of future earthquakes in each grid cell. Finally, the gridded rates are spatially smoothed, and combined with maximum-magnitude models and ground-motion models to compute hazard. We will discuss a few issues that arise for the CEUS: (1) Are the equations used to convert other size measures to moment magnitude suitable for small earthquakes? (2) Can we make better use of the USGS PDE/ComCat catalog? (3) Should we use an alternative declustering approach for induced seismicity in Oklahoma, or even the full catalog? (4) Can the identification of mining-related and other non-tectonic earthquakes be improved?

Preferred Platform: Oral Presentation

Student Presenter: N

Faults and Lineaments of the Western Quebec Seismic Zone

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The Western Quebec Seismic Zone (WQSZ) includes a series of historical earthquakes as large as M 6.2 (Temiscaming, 1935) and frequent low level seismic activity. The activity mainly occurs within two elongated bands: one that parallels the Ottawa River (where faults of the Ottawa-Bonnechere Graben are mapped) and another one oriented NW-SE where most local earthquakes occur (faults positions are not as well known). This project aims at producing a digital map of the faults and lineaments of the entire WQSZ. The digital map will help defining the relationships between earthquakes and faults, one component of seismic hazard assessment. Lineaments were observed mostly from the Digital Elevation Model (DEM) of the Canadian National Topographic Data Base (NTDB) at a scale of 1:250,000. The DEMs illuminated from two directions were used to visually recognize lineaments and georeferenced their surface traces in a Geographic Information System. Since the final goal is to better map the brittle faults that could be reactivated in earthquakes, the ductile structures of the Grenville orogeny are removed from the final product, but kept in the digital database. Brittle structures are generally linear whereas ductile structures are curved, delimit Grenvillian lithologies or present a distinct pattern. Only the lineaments with a length greater than 5 km are considered. From this first detection pass, regional scale lineaments were drawn by interpolating between segment of lineaments where the topography was subdued and did not create a conspicuous trace. Our lineaments were compared with the geological maps of the provincial surveys which often do not differentiate between brittle and ductile faults. We also used the geological maps and the magnetic field to filter out lineaments that coincided with diabase dykes. Our product a 1:750,000 scale map that could be used to study earthquakes of this region.

Preferred Platform: Poster Presentation

Student Presenter: N

How Earthquake Fault Geometry Affects the Relationship Between the M_w and the M_L , m_bL_g , M_N , and M_e Magnitude Scales

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Least squares analysis of numerous data sets between the M_w and the M_L , m_bL_g , M_N , and M_e magnitude scales, in general, show lines or curves with slopes that are less than one. There is little agreement in the observations from one region to another as to the exact values of the empirical constants. This paper addresses this problem. Empirical results show that in “western” North America, M_w is greater than, equal to, and less than M_L while almost all of the earthquakes in “eastern” North America have a moment magnitude value which is less than the other magnitudes. To explain the large differences which exist between the two regions, it is first shown theoretically that the magnitudes which are based on a peak amplitude measurement are approximately equal to the energy magnitude (M_e). This magnitude is based on the square root of the observed seismic trace L_g coda energy. If we define “ p ” as the ratio (M_w/M_e), and “ α ” as the seismic moment scaling constant, and “ β ” the fault aspect ratio (width/length), then it is shown theoretically that $\alpha = 3/2(1+\beta)$ and that $p = 2/3(1+\beta)$. As β varies mathematically from $[1 \rightarrow 2/3 \rightarrow 1/2 \rightarrow 1/3 \rightarrow 0]$, α will vary from $[3.0 \rightarrow 2.5 \rightarrow 2.25 \rightarrow 2.0 \rightarrow 1.5]$, and p will vary from $[4/3 \rightarrow 10/9 \rightarrow 1.0 \rightarrow 8/9 \rightarrow 2/3]$. This shows that by measuring the ratio of M_w/M_e for each earthquake, we can obtain estimates of the corresponding values of “ α ” and “ β ”. To explain how it is possible that width limiting faulting (i.e. L_2 scaling) appears to occur in small to intermediate earthquakes, a crustal layer theory is presented which states that these earthquakes can occur in weak low velocity layers of the crust and that the fault widths are determined by the thicknesses of these layers. The results of a series of numerical experiments are presented which support this theory. These involve estimates of fault dimensions and determining the values of M_w and M_e for earthquakes with constant width faults.

Preferred Platform: Poster Presentation

Student Presenter: N