B03: Physical and Biogeochemical Land Surface Processes in a Changing Climate

Conveners: Vivek Arora[1], Paul Bartlett[2], Chris DeBeer[3] and Andrew Ireson[4]

Co-chairs: Paul Bartlett[2] and Andrew Ireson[4]

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Session Description

The Earth's climate has been warming in recent decades in response to increases in atmospheric carbon dioxide (CO_2) and other greenhouse gases. The interactions between climate change and physical and biogeochemical land surface processes are varied and dynamic. Increasing temperature affects not only the length of the mid-to-high latitude growing season, but also the speed of biogeochemical reactions governing rates of growth, decomposition and nutrient cycles. Evaporation tends to increase with temperature, influencing soil moisture and precipitation patterns, as well as plant moisture stress and soil biogeochemical processes. The CO_2 fertilization effect is an important but poorly understood negative feedback mechanism that may help to mitigate changes in climate by increasing carbon sequestration. The response of nutrient cycles, such as nitrogen, is important for determining whether nutrient availability to plants will enhance or limit expected increases in photosynthetic rates. Changes in temperature and precipitation patterns also have the potential, over time, to alter the distribution of plant functional types over the globe, but the factors controlling the range and success of vegetation species are complex, and so the effect on the net carbon balance of the land surface is uncertain. The extent of seasonal snow and ice cover represents a large positive feedback mechanism, the snow-albedo feedback, which interacts strongly with temperature, precipitation phase, and vegetation distribution. There is a large spread in the simulated albedos for snow-covered surfaces in the CMIP5 climate models, much of which appears to be related to the representation of vegetation masking in the boreal forest, and which contributes to a large spread in the snow albedo feedback in these models. In this session we welcome papers that investigate or model the response of land surface physical and biogeochemical processes to climate change, or that contribute to improved understanding of processes that affect these interactions.

Primary Affiliation: Biogeosciences / Hydrology

NOTE: THIS DOCUMENT CONTAINS INFORMATION FOR ALL SESSION SUB-SECTIONS. PRESENTER ABSTRACTS ARE FOUND AT THE END OF THE DOCUMENT.

SCHEDULE MAY BE SUBJECT TO CHANGE.

ORAL SESSION B03a

Chairs: Paul Bartlett and Andrew Ireson **Room: AERL 120**

Tuesday, May 30th

TIME	AUTHORS	TITLE
11:00	P. Bartlett & L. Wang	Factors affecting winter albedo simulations in boreal environments using CLASS
11:15	M. Nazarbakhsh* & A. Ireson	Understanding the trade-off between soil and vegetation characteristics in controlling the water balance in the southern boreal forest
11:30	W. Skeeter*, A. Christen, G. Henry & T. Lantz	Vegetation influence and environmental controls on greenhouse gas fluxes from a drained thermokarst lake
11:45	A.-A. Laforce*, E. Humphreys & C. Burn	Spatial variability of carbon emissions within a drained lake basin and its surrounding tundra, Illisarvik, NT.
12:00	M. Helbig*, L.E. Chasmer, A.R. Desai, M. Detto, N. Kljun, W.L. Quinton, C.C. Treat & O. Sonnentag	Thawing boreal forest-wetland landscapes as components of regional and global climate systems
12:15	S.E. Irvine*, M. Strack, & J.S. Price	DOC Transport in a Constructed Watershed in the Athabasca Oil Sands Region, Alberta

POSTER SESSION B03

Chairs: Vivek Arora, Paul Bartlett, Chris DeBeer, and Andrew Ireson

Room: ESB Atrium, Wednesday May 31st

Poster No.	AUTHORS	TITLE
P01-B03	M.Q. Morison*, R.M. Petrone, M.L. Macrae & L. Fishback	Impacts of hydroclimatic change on nutrient cycling in thermokarst-impacted northern peatlands

P02-B03	J. Tian*, Z. Lindo & B. Branfireun	Climate change alters peatland carbon cycling through plant biomass allocation

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SUBMITTED ABSTRACTS

B03-01: Thawing boreal forest-wetland landscapes as components of regional and global climate systems

Manuel Helbig[1,2*], Laura E Chasmer[3], Ankur R Desai[4], Matteo Detto[5], Natascha Kljun[6], William L Quinton[7], Claire C Treat[8] and Oliver Sonnentag[1,2]

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Abstract

Boreal landscapes in the Taiga Plains of northwestern Canada store large amounts of soil organic carbon (C) and play an important role in the regional and global climate system. Warming-induced permafrost thaw in organic-rich lowlands causes expansion of permafrost-free wetlands at the expense of boreal forests. To better understand how these land cover changes affect land-atmosphere interactions, we combine nested eddy covariance measurements of water, energy, CO_2 and CH_4 fluxes from a thawing boreal forest-wetland landscape with flux footprint and planetary boundary layer modeling, remote sensing data, paleoecological records, and climate projections. Thaw-induced forest loss modifies land-atmosphere energy fluxes through changes in aerodynamic and ecophysiological surface properties. Increasing albedo decreases available energy, while decreasing surface roughness and increasing wetness enhance latent heat at the expense of sensible heat fluxes. These energy flux changes indicate a regional cooling while enhancing atmospheric humidity. Thaw-induced wetland expansion increases landscape CH_4emissions inducing a positive net radiative greenhouse gas forcing. The current wetland expansion rate (0.26±0.05 % yr^{-1}) increases landscape CH_4 emissions by 0.034±0.007 g CH_4 m^{-2} yr^{-1}. Long-term net CO_2 uptake typical of these landscapes (50 – 150 g CO_2 m^{-2} yr^{-1}) are too small to compensate the associated climate warming effect until the end of the 21st century. The thawing landscape acts as net annual CO_2 sink (73±22 g CO_2 m^{-2} yr^{-1}, 2015-2016). Landscape net CO_2 uptake does not change with wetland expansion, as enhanced gross primary productivity (GPP) is compensated by increased ecosystem respiration (ER). In contrast, direct impacts of increasing air temperatures and decreasing incoming shortwave radiation on net CO_2 fluxes appear to be larger. For a high warming scenario, modeled increases in ER exceed increases in

GPP significantly, inducing a net annual CO_2 release. For a moderate warming scenario, ER and GPP increases are of similar magnitude.
Presentation type: Oral

B03-02: Understanding the trade-off between soil and vegetation characteristics in controlling the water balance in the southern boreal forest.

Mahtab Nazarbakhsh[1*] and Andrew Ireson[1]

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Abstract
Evapotranspiration, *ET*, is the key linkage between the water, energy and carbon cycles. In the southern boreal forest, as in other sub-humid climates, *ET* is the dominant loss term in the water balance, and small errors in *ET* will result in very large errors in predictions of runoff or groundwater recharge. Land surface properties that control *ET* are divided into plant and soil characteristics. Important plant physiological characteristics include the leaf area index, stomatal conductance and rooting depth, all of which are in reality dynamic, changing seasonally and inter-annually in response to climatic and hydrologic (soil moisture) conditions. Typically, Land Surface Schemes and hydrological models use static plant parameterisations (often with prescribed seasonal characteristics), and calibrated soil hydraulic properties. However, it can be shown that changes in the water balance caused by changing the root depth, can be compensated for by recalibrating the soil parameters. Since the rooting depth is uncertain, hard to measure, and dynamic, using fixed, arbitrary depths may lead to errors in the calibration of hydraulic properties. We seek to explore this issue systematically, using three models with progressively increasing complexity: the first has no plant representation at all, and measured *ET* is imposed on the model which simulates changes in soil moisture, *dS*, and drainage, *D*; the second (CLASS) uses prescribed vegetation characteristics, and simulates *ET*, *dS* and *D*; and the third (CLASS-CTEM) using dynamic vegetation, again to simulate *ET*, *dS* and *D*. The model is applied to the Old Jack Pine BERMs site, where we have long records of observations of *ET*, *dS* and water table response that is related to *D*. Past models applied to this site have systematically over predicted *ET*.

Presentation type: Oral

B03-03: Vegetation influence and environmental controls on greenhouse gas fluxes from a drained thermokarst lake

Wesley Skeeter[1*], Andreas Christen[1], Greg Henry[1] and Trevor Lantz[2]

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Abstract
Terrestrial Arctic landscapes presently constitute a net greenhouse gas sink, but climate warming and permafrost disturbances are anticipated to weaken or offset this sink. Methane (CH_4) and carbon dioxide (CO_2) fluxes were measured using eddy covariance at Illisarvik, a 0.16 km^2experimentally drained thermokarst lake basin (DTLB) on Richards Island, NWT, Canada in the summer of 2016. Vegetation at the site was diverse but characterized by patches of willow, grasses and sedges with some bare ground and a small pond in the center of the basin. Measurements occurred between July 10th and August 7th, covering the peak growing season. Temperature and wind conditions were highly variable, net evapotranspiration exceeded precipitation, and soil water content decreased through the study period. CO_2 uptake was strong (-8.36 g $m^{-2}d^{-1}$); fluxes followed a marked diurnal pattern but had no seasonal trend. By contrast CH_4 emissions were weak (2.5 mg m^{-2} d^{-1}), highly variable, followed no diurnal pattern, and exhibited a decreasing trend. Footprint modeling was used to estimate the source area for the half hourly flux measurements. The footprint climatology was overlaid on drone imagery and data from a vegetation survey to determine the impact various plant communities had on the fluxes. The sedges, dense willows, and open water were relatively strong sources of CH_4 while the grasses and bare areas were very weak CH_4 sources. Sedge- and willow-dominated areas were also strong sinks for CO_2 while the areas dominated by grasses were a weak sink or even net sources of CO_2. Primary environmental controls over CO_2 fluxes were photon flux density and soil temperatures. The relationships were less well defined for CH_4 with volumetric water content being the most influential factor. Results suggest Illisarvik is a net sink for GHGs.

Presentation type: Oral

B03-04: Spatial variability of carbon emissions within a drained lake basin and its surrounding tundra, Illisarvik, NT.

Andree-Anne Laforce[1*], Elyn Humphreys[2] and Chris Burn[2]

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[2] Department of Geography and Environmental Studies, Carleton University

Abstract
In 1978, a small thermokarst lake known as Illisarvik on Richards Island (NT) was drained. Since then, vegetation succession and permafrost growth have been monitored and have demonstrated great spatial variability throughout the basin. This study aims to relate vegetation and soil conditions to the spatial variations in summer CO_2 and CH_4 emissions in this environment to better understand the interaction of these controls on carbon fluxes from Arctic sites. The field site covers a 500 m x 350 m area where ten vegetation units including one unvegetated area on the shoreline of a pond were selected to represent the spatial variability of the basin. A static, non-steady state chamber system was used to measure CO_2 and CH_4 emissions from collars with and without aboveground vegetation in each vegetation unit. Microclimate characteristics including thaw depth, soil moisture and near surface soil temperature were monitored. Radiocarbon dating of the gas fluxes was also done to help understand the source of carbon released from these soils. We hypothesized that carbon emissions associated with heterotrophic and belowground autotrophic respiration will be greatest in areas that are moist and warm with deep active layers in areas with taller vegetation. Thaw depth was deepest (> 100 cm) at sites with willows (both tall and low willow shrubs) and the bare sand at the shoreline. However, emissions of CO_2 were greatest at the wet sedge sites and the dwarf shrub tundra site where thaw depths were less. CO_2 emissions at all sites were greater with aboveground vegetation intact. As expected, CH_4 emissions were greatest at the wettest sites dominated by sedges. The age of the carbon in emitted CO_2 at each site was modern except for the one shoreline site without vegetation where carbon was dated as 2000 BP. These results add to our knowledge of the functioning of a post-drainage Arctic ecosystem and its possible impacts on the climate through greenhouse gas emissions.

Presentation type: Oral

B03-05: Factors affecting winter albedo simulations in boreal environments using CLASS

Paul Bartlett and Libo Wang

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Abstract
The simulation of winter albedo in boreal and northern environments has been a particular challenge for land surface modellers. Assessments of CMIP3 and CMIP5 climate models revealed that many simulations are characterized by overestimation of albedo in the boreal forest. Recent studies suggest that poor simulations of the snow masking effect of forests, as well as incorrect plant functional type and biases in leaf area index simulation are the primary causes of albedo errors. The Canadian Land Surface Scheme (CLASS) has, at various times, shown positive and negative winter (in the presence of snow) albedo biases in forests, related to the treatment of snow masking by vegetation, canopy snow interaction, bias in canopy cover fraction, and the treatment of subgrid-lakes. Here we present a brief overview of some of the key developments in CLASS with respect to the simulation of winter albedo in boreal forests, including historical changes to the representation of snow masking by vegetation, canopy interception and canopy albedo values. Using our latest version (3.6.2), we also examine the sensitivity of simulated albedo to forcing at local and regional scales, and we present preliminary results from selected ESM-SnowMIP (Earth System Model – Snow Model Intercomparison Project) simulations as an indication of current performance and future direction.

Presentation type: Oral

B03-6: DOC Transport in a Constructed Watershed in the Athabasca Oil Sands Region, Alberta

S.E. Irvine[1*], M. Strack[2], J.S. Price[2]

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Abstract

In the Western Boreal Plain (WBP) fens comprise up to 50% of the landscape, however much of this area has been disturbed due to bitumen extraction in the Athabasca Oil Sands Region. Since there is a legal requirement to return equivalent land capability, an experimental fen watershed was constructed to assess peatland construction success. This watershed comprises a constructed fen, three reclaimed and one natural hillslope and an upland. Dissolved organic carbon (DOC) transport can represent an important component of the carbon cycle and mobilize DOC to downstream ecosystems. This can occur through surface runoff, groundwater, or discharge. Though surface runoff is limited in the WBP due to its sub-humid climate, the constructed fen frequently experiences surface runoff on the reclaimed hillslopes during precipitation events. Therefore, it is important to understand how the hydrology of this constructed watershed mobilizes DOC. We report on hydrologic DOC fluxes and quality within this watershed during 2015 (May-August) and 2016 (July-August). Groundwater and runoff DOC inputs are larger than outputs, being primarily controlled by the groundwater source. DOC concentrations are similar in groundwater, upland, and hillslope runoff sources indicating that the volume of water is more important for DOC transport than source material. However, DOC quality is not comparable, as DOC from the hillslopes appears larger and more aromatic than what is mobilized from the upland, with the groundwater DOC appearing the smallest and least aromatic. This is uncharacteristic of groundwater, which may be due to the presence of poorly characterized DOC sources such as naphthenic acid. Hydrologic losses of DOC are minimal, as outflow from the fen is restricted to surface outflow (10 and 7 mm in 2015 and 2016). DOC at the outflow appears small and non-aromatic, therefore it is unlikely to be sourced from the hillslopes, and minimally from the upland.

Presentation type: oral

P01-B03: Impacts of hydroclimatic change on nutrient cycling in thermokarst-impacted northern peatlands

Matthew Q Morison[1*], Richard M Petrone[1], Merrin L Macrae[1] and LeeAnn Fishback[2]

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Abstract
Northern peatlands contain vast stocks of organic matter, the accumulation of which is driven by a slow rate of decomposition, limited by temperature and oxygen, while primary productivity is limited by the presence of bioavailable nutrient species. Further, across the circumpolar north, the degradation of permafrost has resulted in a significant change to land cover, including an increase in thermokarst extent, which can alter oxic soil conditions. Climatically-driven changes to hydrology and temperature have the potential to impact biogeochemical processes within the landscape, which has implications for plant productivity, greenhouse gas flux, and surface water quality. To assess the impacts of changing moisture and thermal conditions on the mineralization of nutrients in northern peatland landscapes, a set of cores were extracted from several landscape units along primary gradients of moisture and topographic position (peat plateaus, sedge lawns, channel fens, and thermokarst) in the Hudson Bay Lowlands in subarctic Canada. The cores were sectioned by depth to determine the spatial distribution of nitrate, ammonium, and orthophosphate pools. Using a factorial design, the cores were subjected to a range of temperature (4°, 12°, and 20° C) and moisture treatments (saturated, field moist, and air dried) in an oxic environment over a three weeks to determine their relative controls on nutrient mineralization rates. Warmer temperatures resulted in significantly greater immobilization of phosphate in both field moist and saturated treatments than within dry treatments. Temperature exerted a strong control on nitrification rates, while downslope landscape units (channel fen, thermokarst) showed significantly higher nitrification rates than uplands. Ammonium mineralization showed the greatest variance in response across treatments in thermokarst material. This work provides novel insight to the impact of changing temperature and moisture conditions on nutrient cycling processes in northern peatland landscapes along two gradients of spatial position (landscape unit and depth).

Presentation type: Poster

P02-B03: Climate change alters peatland carbon cycling through plant biomass allocation

Jing Tian[1*] Zoë Lindo[1] and Brian Branfireun[1,2]

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Abstract
Northern peatlands are long-term, stable carbon (C) sinks due to the slow decomposition rates under a normally cool and wet environment. However, the C stored in northern peatlands is potentially sensitive to environmental disturbance such as increased temperature, and the effects of atmospheric carbon dioxide (CO_2) concentrations on plant growth and community composition. Previous research has shown that plant biomass, especially belowground root production and decomposition, plays an important role in peatland C cycling in ombrotrophic bogs however, there is still little research on more minerotrophic, graminoid-dominated fens – a ubiquitous but understudied peatland type. A full factorial study using replicated mesocosms was done to experimentally examine the individual and interactive effects of future climate conditions including increased temperature and elevated atmospheric CO_2 concentration on peatland plant growth, porewater dissolved organic carbon (DOC) and CO_2release from intermediate fen in experimental greenhouses at the Biotron Experimental Climate Change Research Center at Western University over one full growing season in 2015. Our results show that experimentally increased temperature and elevated atmospheric CO_2alters plant growth and the allocation of aboveground and belowground biomass in conjunction with the accelerated peat decomposition, shown by increased pore water DOC concentrations and the increase in CO_2flux from the mesocosm peat soils. In addition, increased temperature treatments increased the net C export via DOC (up to ~91%) and CO_2(up to ~3.97 g C m^{-2} d^{-1}) from the mesocosms over a longer growing season until October. These results highlight the need to better understand aboveground/belowground linkages and the implications for ecosystem functions such as carbon storage in graminoid-dominated peatlands and their potential feedbacks to future climate change.

Presentation type: Poster