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Poster Abstracts

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Toolik Field Station Mission:

To support research and education that creates a greater understanding of the Arctic and its relationship to the global environment.

Purpose of the All Scientists Meeting:

To promote collaboration and synthesis among Toolik Field Station researchers and others working in the Arctic.

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Abstracts are listed in alphabetical order by author.

Growth rings and xylem anatomy of Alaskan tundra shrubs under experimental warming and snow fence treatment (Toolik Lake)

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The goal of our study is to explore growth response of arctic shrubs to both ongoing and predicted temperature and snow depth increase in tundra ecosystem. Using both dendrochronological methods and quantitative wood anatomy we investigated shrubs' annual growth rings applied to plants growing under control and experimental treatments in Toolik Lake, Northern Alaska. Specifically we evaluated the effects of a 21 year experimental warming (due to open top chambers, OTC's) and snow depth increases (in the inter-medium snow zone) on the growth rings pattern of two common shrub species of Northern Alaska, i.e. *Betula nana* and *Salix pulchra* in a moist tussock tundra plots. Thanks to quantitative wood anatomical analyses performed in annual resolution ten xylem-based chronologies were established for both experimental and control plots and climate-growth relationship analyses were performed for each chronology.

Findings for *Betula nana* indicate that birch shrubs respond positively to both increased snow depth and warmer summer temperatures induced experimentally. Specifically, the highest growth response (ring area and mean ring width) was indicated for snow fence shrubs. Changes in secondary growth pattern of birch where highly associated with a specific xylem adjustments such as increase in vessels number as well increase in mean and maximum vessels size. The associated and improved hydraulic conductivity of shrubs from both experimental plots provided a mechanistic understanding of an improved *Betula nana* shrub growth in response to warming and additional snow across more than two decades of experimental design. Analyses for *Salix pulchra* shrubs are currently performed.

Biogenic silica accumulation varies across plant functional type in Arctic tussock tundra

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The importance of a dynamic biological silica (SiO_2) cycle in terrestrial landscapes has recently been emphasized, but the majority of terrestrial Si research has thus far focused on agricultural and forested ecosystems. Knowledge of terrestrial silica cycling in the Arctic is severely lacking and our understanding of how climate change will impact the Arctic silica cycle is limited. Here we quantify biogenic silica (BSi) accumulation in above and belowground portions of tussock tundra vegetation and elucidate how silica storage shifts across plant functional type. We quantified BSi accumulation in three moist acidic tundra (MAT) sites (Coldfoot, Toolik, Sagwon) spanning a 300 km latitudinal gradient in central and northern Alaska, USA. At Toolik, we also examined plant silica accumulation across the three main types of tundra found in the Arctic (MAT, moist non-acidic tundra (MNT), and wet sedge tundra). BSi concentrations in live Eriophorum vaginatum, the dominant plant species across the tussock tundra, were significantly ($p=0.04$) different across the three main sites, but these differences did not correlate with latitude. Concentrations of BSi in live aboveground tissue were highest in the graminoid species (0.55 ± 0.07% SiO_2 by dry wt. in sedges from wet sedge tundra, and 0.27 ± 0.01% in E. vaginatum across the three MAT sites). Both inter-tussock tundra species and shrubs contained substantially lower Si concentrations than the E. vaginatum growing in tussocks. Despite low Si concentrations in shrub species, our calculations suggest conversion of tussock to shrub tundra will increase BSi storage in Arctic land plants due to higher biomass associated with shrubs. Our results have implications for how shifts in vegetation cover associated with climatic warming is altering silica storage in tussock tundra vegetation, with potential consequences for the rates and timing of Si delivery to Arctic receiving waters.

Flowpath of snowmelt water in an ice-covered arctic lake

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At springtime, the melting snow on the landscape enables high discharge enriched in dissolved organic carbon (DOC) into ice-covered lakes. However, empirical studies tracking this inflow during the spring melt are rare, and the fate of its solutes remains uncertain. The extent to which the snowmelt loading spreads, mixes vertical, and is retained is important for metabolism within the lake. Our goal was to characterize these transport processes in Toolik Lake, Alaska, during spring 2013, 2014, and 2015. We traced the path of inflowing meltwaters by combining the use of high resolution time series data for conductance, temperature, and fluorescence with daily profiles on cross lake transects. Fluorescence signal was largely due to DOC, so we used it as a tracer to quantify DOC spreading and retention in the lake. Water samples were collected and analyzed to determine DOC concentration. We also measured ambient meteorology, stream discharge, conductance, and temperature. The flowpath of snowmelt water into Toolik Lake depended on the density differences between stream and lake surface water, the magnitude and timing of the stream discharge, and the interanual variability in snowcover and rate of warming in spring. During early snowmelt, cold and fresh stream water entered the lake within a layer ~3 m thick under the ice with high DOC concentrations (>750 μM) and low velocities of O(0.001) m/s, which spread considerably in the horizontal. As discharge increased, stream water mixed with the inlet basin water. Mixed waters with DOC concentrations of ~550 μM flowed into the main basin primarily along a preferential path to the outlet with velocities ~two to five times larger than during early snowmelt. We estimated ~60% of the DOC introduced by the time of the largest peak discharge was retained within the lake about a week after. After the last peak discharge, penetrative convection was constrained by the step changes in density from the incoming plume with multiple mixing zones which increased in depth as the ice thinned. The vertical mixing and horizontal density-driven flows contributed to retention of solutes. The differences in ambient meteorology, magnitude of discharge, and density of incoming water during spring enable interpretations and predictions of the fate of solutes flowing into lakes during snowmelt under variable weather regimes.

Modeling the growth of *Eriophorum vaginatum L.*

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Eriophorum vaginatum L. is a rhizomatous, tussock forming, perennial sedge commonly found in Arctic tundra environments. Tussocks are well suited to harsh nutrient poor environments and tussock tundra is common in Alaska, Canada and Northeastern Russia accounting for ~24% of Arctic land area. Tussocks play important roles in Arctic ecosystem biogeochemistry and carbon (C) storage. However, the environmental and physical factors controlling their size, distribution across the landscape and growth are poorly understood as a result of their growth form and slow growth rate (~150 years). In order to better understand the role of tussocks in tussock tundra ecosystem C storage, understand the potential impacts of climate change on tussock tundra and allow for this species to be better represented in ecosystem models we amassed data from a core site at Toolik field station in North Slope Alaska as well as other Arctic locations. Using this information we constructed and explored a modeling framework to explain carbon storage and growth in *E. vaginatum*. This framework will guide further investigation of the physical and environmental factors controlling this particular growth form.

Implications of shrub expansion on soil carbon sequestration

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Implications of shrub expansion on soil carbon sequestration and permafrost stability, greenness, plant cover and productivity, is a critical driver of both the carbon and the surface energy budget of terrestrial ecosystems. While some parts of the rapidly warming Arctic have experienced greening, others are undergoing browning, and it not clear how the observed changes in plant productivity and composition will affect annual carbon fluxes, soils carbon storage, and the rate of permafrost thaw. We used soil surveys along gradients of increasing shrub density in the Toolik area to quantify current relationships between shrub cover, soil carbon stocks and active layer depth.

Our surveys show that areas dominated by shrub tundra have higher carbon stocks, with more microbially-processed organic material as indicated by lower C:N ratios, shorter alkane chain length and stable nitrogen isotope ratios. Laboratory soil incubation experiments further reveal a low priming potential in moist acidic tussock tundra soil, indicating that increasing shrub litter inputs are unlikely to result in large losses of existing soil carbon. The soil surveys further demonstrate very clearly that areas with higher shrub density have shallower active layers. Together, our data highlights the need to more comprehensive datasets on shrub expansion (as well as browning) and that shrub expansion should be considered in projections of permafrost degradation.

Ecotypic differences in the phenology of the tundra species *Eriophorum vaginatum*

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Locally adapted populations (ecotypes) of *Eriophorum vaginatum* have been identified across the distribution of *E. vaginatum* using measures of biomass, physiology, and survival in reciprocal transplant experiments. However, little is known about how these ecotypes differ over the course of a growing season. Evidence for local adaptation of *E. vaginatum* leads to the hypothesis that they may suffer from adaptive lag should gene flow northwards fail to track a rapidly changing climate. Consequently, there is a need to understand how populations differ in their growth patterns, which environmental factors have selected for these patterns, and how they may be influenced by climate change.
Mature tussocks from across a latitudinal gradient (65-70° N) were transplanted into a common garden at Toolik Lake where half were warmed using open top chambers. During the 2015 and 2016 growing seasons, we measured leaf length every week to track growth rates, timing of senescence, and biomass accumulation. We found that growth rates were similar across populations and between years and were not affected by warming. However, southern populations accumulated significantly more biomass, largely because they started to senesce later. In the second season of measurement, senescence of most populations occurred later due to a delayed onset of the growing season, but the differences between populations were retained. The timing of senescence was not affected by warming. These results suggest that *E. vaginatum* populations are adapted to differences in length of growing season that are associated with their home sites. As climate warms and growing seasons lengthen, this key tundra species may be unable to respond accordingly and may be out-competed by more responsive species.

Resilience of plant communities to changes in climate and fire regime: palaeoecological insights from arctic peatlands in Alaska

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High-latitude ecosystems have experienced higher-amplitude climate warming than other parts of the globe in recent decades, and are projected to continue to warm in the future, with consequences for vegetation communities, peat accumulation rates and carbon cycling (Yu 2012; Kuhry et al., 2013). Specifically, tundra vegetation communities are increasing in terms of cover and height, and fires are becoming more frequent (Myers-Smith et al., 2013). These processes restrict the growth of other plant species by limiting light availability and increasing the frequency and intensity of fire regime. Most of the data concerning the response of plant communities (species, biomass phenology) to recent warming is based on current observational studies, with comparatively little research focusing on centennial to millennial scale changes. In addition, there are limitations in our understanding of fire regime dynamics and in particular of the tolerance of tundra plant species to increased fire frequencies. Therefore, studies that focus on long-term vegetation dynamics under varying environmental conditions are indispensable to our understanding of the contemporary changes in vegetation and the most likely long-term response to future climatic changes. In this palaeoecological study, we use the fossil record (plant macroremains, testate amoebae, macro- and microcharcoal, carbon accumulation) and ^{210}Pb (for the last ~150 years) and AMS ^{14}C measurements to determine the response of arctic plant communities to past climate warming in northern Alaska. Specificall aims of our palaeoecological studies are: i) to reconstruct local and regional vegetation changes during the last millennium; ii) to evaluate the influence of changes in climate and autogenous succession in the development of arctic plant communities; iii) to explore fire regime dynamics and vegetation feedback on fire activity; and iv) to determine shifts in carbon accumulation rates. We hypothesize that during warm climate episodes such as the Medieval Warm Period (MWP) or the more recent decades, moss-dominated vegetation communities become replaced by shrub-dominated communities and there is increased carbon accumulation rates in arctic peatlands. To carry out our paleoecological studies we selected eight peatland sites along a South-North transect, from the foothills of the Brooks Range, Toolik FS to Prudhoe Bay, along the road No. 11. Additionally, in three of these peatlands we conduct replicate multi-proxy and high-resolution palaeoecological studies by analysing two cores. This replication improves the reliability of the paleoecological interpretations. The results from peatland sites in Alaska will allow for intercontinental comparison with both North America and European data of Arctic vegetation development, fire regime and carbon accumulation rates during the last millenium.

Vegetation succession, carbon accumulation and hydrological change in sub-Arctic peatlands (Abisko, N. Sweden)

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We present results from a multiproxy study on the hydrological, ecological and carbon accumulation dynamics of two sub-Arctic peatlands in Abisko, Sweden. High-resolution analyses of plant macrofossils, testate amoebae, pollen, mineral content, bulk density, and carbon and nitrogen were undertaken. The peat records were dated using tephrochronology, ^{14}C and ^{210}Pb. Local plant succession and hydrological changes in peatlands were synchronous with climatic shifts, although autogenous plant succession towards ombrotrophic status during peatland development was also apparent. The Marooned peatland experienced a shift ca. 2250 cal yr BP from rich to poor-fen, as indicated by the appearance of *Sphagnum fuscum.* At Stordalen, a major shift to wetter conditions occurred between 500-250 cal yr BP, which is most probably associated with climate change during the Little Ice Age. During the last few decades we observe a deepening of water table and an increase in shrub pollen, coinciding with recent climate warming and the associated expansion of shrub communities across the Arctic zone. Rates of carbon accumulation vary greatly between the sites, illustrating the importance of local vegetation communities, hydrology and permafrost dynamics. We also use multiproxy data to elucidate the palaeoecology of *Sphagnum lindbergii* and find it is indicative of wet conditions in peatlands.

Development of polygon mires/ice-wedge polygon: examples from Lena River Delta (N Russia)

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Mapping tundra vegetation communities near Toolik Field Station at 1-meter resolution

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High-resolution mapping of vegetation community distribution enables accurate accounting of ecosystem features and functions including wildlife habitat, carbon and nutrient balance, hydrological and snow dynamics, and radiative balance. Additionally, high resolution vegetation maps permit spatial calibration and validation of coarser, large-extent maps that are required inputs for large climate and carbon models. However, tundra vegetation distribution responds strongly to slight gradients in microenvironment, and therefore can be heterogeneous at very fine (1 m) scales. This makes mapping tundra vegetation at scales relevant to vegetation communities challenging, especially because high-resolution spatial input data can be difficult to acquire. In 2013, our research group acquired ~12 km2 of high-density aerial lidar and high-resolution (5 cm) RGBN aerial imagery in three footprints near Toolik Lake, Alaska. In the past year, we have exploited these datasets to produce high-resolution spatial models of canopy volume (0.15 m) and shrub biomass (0.8 m) using lidar- and imagery-derived metrics in a Random Forest modeling approach. We are now in the process of applying a similar approach to model distribution of vegetation communities across our lidar/imagery data footprints, with a goal of producing high-resolution (1 m) vegetation maps for this important research area. To help future map users evaluate the suitability of these maps for their specific applications, we will also provide confusion matrices and model uncertainty maps. These high-resolution maps should prove useful for researchers who require high-resolution spatial vegetation information to plan research campaigns and model ecosystem functions occurring at fine spatial scales.

Soil and plant Hg dynamics at Toolik Field Station

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Introduction: Atmospheric mercury (Hg) can be transported over long distances to remote regions such as the Arctic where it can then deposit and cause detrimental effects to arctic wildlife and humans (AMAP 2009). Little information is known about Hg storage and pools in arctic upland tundra ecosystems, a large receptor area for atmospheric deposition and a major source of Hg to the Arctic Ocean (Fisher et al., 2012). This research aims to improve the understanding of terrestrial Hg cycling in the arctic tundra, a major biome that covers 4% of global land surface area (Bailey, 2014). We focus on determination of tundra vegetation and soil Hg concentrations and pools and their potential origin and fate using geochemical tracers. We further aim to characterize spatial Hg pool sizes and depth patterns across upland and wetland soils and in permafrost soil layers. Additionally, we characterized patterns of Hg plant concentrations, growing season uptake, and contributions to litterfall decomposition, with a particular focus on dominant plant species and functional groups.

Methods: Soil and vegetation samples collected at the Toolik Field Station in summer of 2014 and 2015 were analyzed for total Hg concentration, pH, soil texture, bulk density, soil moisture content, organic and total carbon, nitrogen, along with major and trace elements. Select samples were age-dated using carbon-14 analysis and analyzed for organic methyl-Hg. Hg pool sizes were estimated by scaling up Hg soil concentrations using soil bulk density measurements. Contributions of exogenic and lithogenic Hg were estimated using reference concentrations of conservative elements (Al, Ti, Zr) in bedrock as described in Guedron et al., (2006). Separated vegetation Hg concentration analysis was performed on dominant plant species and functional groups and on plants collected throughout growing season to evaluate concentration changes.

Results: Results from Toolik station show total Hg concentrations in tundra vegetation averaging 112±15 µg kg-1,. Compared to Hg levels found at many temperate sites (e.g., Obrist et al., 2012), vegetation Hg levels were higher in arctic vegetation which is attributable to a high representation of lichen and mosses with higher Hg concentrations. Seasonal changes in plant Hg concentration throughout the growing season showed significant uptake of atmospheric Hg ranging from +22% to +83% from May to August for dominant species. Tundra soil Hg concentrations were 151±7 µg kg-1 in organic soils and 98±6 µg kg-1 in mineral soils, and much higher than the range of 20-50 µg kg-1 reported from upper soils in temperate areas (Amos et al., 2015). Vertical concentration patterns were relatively constant, in contrast to temperate sites showing strong declines with depth that follow the distribution of organic carbon. Permafrost soil Hg concentrations, on the other hand, were lower (average

40±0.2 ug kg-1). Mass calculations show that Hg mass in the upper 40 cm of the soil profile (200-500 g ha-1) was primarily stored in mineral soil layers (over 90%). Hg mass showed substantial spatial variability, particularly along an upland-wetland gradient where wetland Hg pools were much lower due to an absence of mineral soil layer. Methyl-Hg were low in soils, on average below 3% of total Hg and below detection limit (0.1 ng g-1) in permafrost soils.
Principle component analyses including major and trace elements showed that soil Hg was also correlated to organic matter, although weaker than in temperate sites. Soil Hg was independent of geogenic soil elements indicating that soil Hg was not of lithogenic origin but derived from atmospheric sources. Carbon-14 dating showed over 7,000 years old organic carbon in mineral soils of the active layer, and we found that highest concentrations of soil Hg were observed in the oldest dated layers, suggesting that high concentrations may be caused by a long legacy of atmospheric deposition and retention in soils.

Conclusion: Results of this study show substantial Hg levels in tundra plants and soils, exceeding levels often observed at temperate sites closer to pollution sources. Given the high levels of Hg in the tundra and potential impact of global change, including thawing of permafrost and increased occurrence of wildfires, the terrestrial tundra Hg dynamics needs to be understood to constrain potential impacts for tundra wildlife and Hg runoff to lakes and the Arctic Ocean.

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Investigating greenhouse gas fluxes from tundra soils during freeze and thaw cycles using GC-MS flux chambers

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Arctic tundra soils represent significant carbon stores that release greenhouse gases such as methane (CH_4) and carbon dioxide (CO_2) particularly during thawing periods. As the atmospheric lifetime and radiative forcing of each of these species differs, it is important to understand the mechanisms by which carbon release may preferentially be in favour of one species over the other. In situ observations of CH_4 and CO_2 concentrations were hence undertaken within and above the soils at the Toolik Field Station over a 2-year period. Field observations showed both net oxidation of CH_4 and production of CO_2 in tundra soils, and suggest that fluxes of both species from the soil are subject to different temperature sensitivities and hysteresis effects upon freezing and thawing.
To investigate the temperature sensitivity and potential hysteresis effect for CO_2 and CH_4 dynamics, soil core samples from the Toolik field station were incubated in temperature-controlled GC-MS flux chambers and temperatures were shifted incrementally between -10 ˚C and 5 ˚C. Initial results show cessation all oxidation and production of greenhouse gases (GHG) below -1 ˚C, although field measurements showed activity to continue under much colder temperatures. Net CH_4 fluxes altered with soil type and temperature, whereby O and A horizon soils showed net oxidation of CH_4 above 2 ˚C when thawing, yet the net oxidation flux continued below 1 ˚C during freezing. B horizon soil showed net CH_4 production above -1 ˚C when thawing, yet this flux stopped at 1 ˚C when freezing. O and A horizon soils showed production of CO_2 above 2 ˚C (thawing) and -1 ˚C (freezing) whereas B horizon soil showed CO_2 production above -1 ˚C (thawing) and 1 ˚C (freezing). These results show different temperature sensitivity of GHG production and oxidation as well as differences between thawing and freezing cycles.

Assessing seedling recruitment in retrogressive thaw slumps in the Alaskan Low Arctic

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Thermal erosion of permafrost soils is implicated in post-disturbance shifts from moist acidic tussock tundra (MAT) to shrub tundra in the Alaskan Low Arctic. Tall birch and willow shrub thickets (> 0.5 m) are observed in stabilized retrogressive thaw slumps (amphitheater-sized gullies in hillsides formed by thaw and mass soil wasting, hereafter RTS). RTS feature sheltered microsites stripped of vegetation; re-vegetation may occur through increased seedling recruitment. We expected greater recruitment in RTS versus undisturbed MAT through higher in situ seedling counts and seedbank viability. Seedbanks should show post-RTS tradeoffs in quantity and quality, with young seedbanks containing fewer, mostly viable seed whose net viability decreases as old seeds accumulate. We made pairwise comparisons of in-situ seedling counts, seedbank viability (percent germination), and seed density (seeds m-2) of soil seedbanks across a chronosequence of RTS and nearby undisturbed MAT (n = 8 sample areas) at two sites near Toolik Lake, Alaska. Both sites feature RTS aged by a previous study through shrub ring counts and radiocarbon dated peat. RTS were coded young (1-10 y.a.), middle-aged (10-29 y.a.) and old (> 30 y.a.). Undisturbed MAT areas were not aged but likely undisturbed by RTS for 30 – 300 years. We found 6 to 40 times more in-situ seedlings in younger RTS versus older RTS, and no seedlings in undisturbed MAT. Younger RTS had more willow and birch seedlings than older RTS. Higher in-situ seedling counts occurred with bare soil, absence of shrubs, and a decrease in local elevation suggesting sheltering effects of RTS. Seedbank viability was unrelated to seedbank size. Seedbank size increased with age across one RTS chronosequence, but not at the other. Percent germination decreased with age at one RTS chronosequence, but was not different at the other. Greater percent germination was correlated with higher in situ seedling counts at one young RTS, suggesting that post-disturbance re-colonization at this site is occurring from the seedbank. Willow and birch germination was 1-2% overall, suggesting recruitment may be lower. Canonical correspondence analysis showed differences in seedbank size, viability, and species composition associated with location. Our results suggest some RTS in the Alaskan Low Arctic may facilitate greater seedling recruitment, which may in part explain tall shrub thickets.

Greenhouse gas (CO_2, CH_4 & N_2O) feedbacks are regulated by phenological changes in herbivore-vegetation interactions in Alaskan coastal tundra

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Changing phenology is a central component of climate change in northern ecosystems. Phenological changes, such as advancement of the growing season, are particularly important in ecosystems that host long-distance migratory herbivores which alter local biogeochemical cycling through grazing, trampling and defecation, and have important effects on primary production and patterns of greenhouse gas fluxes. In the Yukon-Kuskokwim River Delta in western Alaska, such changes have created the potential for a 'phenological mismatch' between the rapidly advancing growing season, and the timing of migration of ca. one million herbivorous geese to this region in the summer. Here we investigated the effects of this potential mismatch on greenhouse gas fluxes (CO_2, CH_4 and N_2O) through a replicated factorial experiment in which we manipulated the onset of the growing season (advanced vs. ambient) and timing of grazing (early, typical, late or none).

Our plot-scale measurements indicated that grazed coastal tundra was a small sink of CO_2 during the growing season (~4 µmol m-2 s-1). CH4 emissions were higher in the early season (~20-80 nmols m-2 s-1) than later in the growing season (~0-40 nmols m-2 s-1) and N_2O emissions were consistently below 1 nmol m-2 s-1. Both advancing the growing season and delaying the timing of grazing increased net CO_2 uptake. Unlike CO_2 exchange, CH_4 emissions were driven by small-scale heterogeneity in vegetation more than advanced growing season and timing of grazing, and N_2O emissions were negligible under all treatments. These results indicate that while an advancing growing season and a delay in the timing of goose grazing may increase the growing season C sink strength of these grazed systems, CH_4 emissions, which are also sizeable, are not driven by phenological changes, making the future overall greenhouse gas forcing of this region difficult to anticipate.

Comparison of soil-surface temperatures with satellite trends of increasing phytomass in Northern Alaska

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Multiple studies are revealing evidence of wide-spread Arctic "greening". In situ vegetation studies have found increases in biomass and increasing vegetation thickness and height in the region. Here, results from long-term studies at a transect of Circumpolar Active-Layer Monitoring (CALM) sites in northern Alaska show that soil-surface temperatures appear to be reflecting these changes in phytomass. Comparison between previously published NDVI trends computed from GIMMS NDVI3g data set to mean soil-surface temperatures measured at 1-ha plots established in 1995 as part of the NSF ARCSS Flux study show that regional trends can also be seen in plot-level measurements. These results illustrate the importance of long-term research studies to quantify trends in a changing landscape.

Arctic Landscape Conservation Cooperative Research Overview

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Since 2009, the Arctic Landscape Conservation Cooperative (LCC) has supported over 60 projects, with a focus on describing and forecasting arctic ecosystem change. Recent and ongoing research from projects will be highlighted, including an Alaskan Arctic-wide long term monitoring network (http://arcticlcc.org/projects/teon/), an Arctic Coastal Plain Tundra Geomorphology map, and the Imiq Hydroclimate Database and Portal (http://imiq-map.gina.alaska.edu/). In order to better support natural resource management in the face of land use and climate change in the Arctic, the Arctic LCC seeks to expand collaboration on long-term monitoring and research projects with the Toolik science community.

Arctic Tundra Soils: A Microbial Feast That Shrubs Will Cease

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Rapid climate warming may already be driving enhanced decomposition of the vast stocks of carbon in Arctic tundra soils. However, stimulated decomposition may also release nitrogen and support increased plant productivity, potentially counteracting soil carbon losses. At the same time, these two processes interact, with plant derived carbon potentially fueling soil microbes to attack soil organic matter (SOM) to acquire nitrogen- a process known as priming. Thus, differences in the physiology, stoichiometry and microbial interactions among plant species could affect climate-carbon feedbacks. To reconcile these interactive mechanisms, we examined how vegetation type (*Betula nana* and *Eriophorum vaginatum*) and fertilization (short-term and long-term) influenced the decomposition of native SOM after labile carbon and nutrient addition. We hypothesized that labile carbon inputs would stimulate the loss of native SOM, but the magnitude of this effect would be indirectly related to soil nitrogen concentrations (e.g. SOM priming would be highest in N-limited soils). We added isotopically enriched (13C) glucose and ammonium nitrate to soils under shrub (*B. nana*) and tussock (*E. vaginatum*) vegetation. We found that nitrogen additions stimulated priming only in tussock soils, characterized by lower nutrient concentrations and microbial biomass ($p<0.05$). There was no evidence of priming in soils that had been fertilized for >20yrs. Rather, we found that long-term fertilization shifted SOM chemistry towards a greater abundance of recalcitrant SOM, lower microbial biomass, and decreased SOM respiration ($p<0.05$). Our results suggest that, in the short-term, the magnitude of SOM priming is dependent on vegetation and soil nitrogen concentrations, but this effect may not persist if shrubs increase in abundance under climate warming. Therefore, including nitrogen as a control on SOM decomposition and priming is critical to accurately model the effects of climate change on arctic carbon storage.

Circulation and Respiration in Ice-Covered Arctic Lakes

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Arctic lakes are ice-covered 9 months of the year. During at least part of this time, the sediments heat the overlying water. Sediment respiration increases specific conductivity, depletes oxygen, and produces greenhouse gases (GHG). Whether anoxia forms and whether the greenhouse gases are sequestered at depth depends on processes inducing circulation and upward fluxes. Similarly, whether the GHG are released at ice off depends on the extent of vertical mixing at that time. Using time series meteorological data and biogeochemical arrays with temperature, specific conductivity, and optical oxygen sensors in 5 lakes ranging from 1 to 150 ha, we illustrate the connections between meteorological forcing and within lake processes including gravity currents resulting from increased density just above the sediment water interface and internal waves including those induced by winds acting on the surface of the ice and at ice off. We found that CO_2 production was well predicted by the initial rate of oxygen drawdown near the bottom at ice on and that the upward density flux depended on lake size, with values initially high in all lakes but near molecular in lakes of a few hectares in size by mid-winter. Both CO_2 production and within lake vertical fluxes were independent of the rate of cooling in fall and subsequent within lake temperatures under the ice. Anoxia formed near the sediments in all 5 lakes with the concentration of CH_4 dependent, in part, on lake size and depth. Inflowing snowmelt waters flowed under the ice with some mixing with underlying lake water. The loading of DOC and CH_4 depended on the rate of snowmelt. Twenty to fifty percent of the greenhouse gases produced under the ice remained in the lakes by the time thermal stratification was established in summer despite considerable mixing at the time of ice off. These observations and analysis lay a framework for understanding the links between within lake hydrodynamics, within year variability, and the fraction of greenhouse gases produced over the winter which evade at ice off.

Heat stupor in arctic bumblebees: physiological resistance along Polar Circle

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Climate change has been recently pointed out as one of the major causes of extinction in several groups of organisms. Climate change is related to an increase of frequency of extreme event such as heat waves. Bumblebees are robust and hairy bees with hetero-endotherm metabolism that enable them to live in some of the highest-elevation and most northern ecosystems. Which are also the hardest regions hit by climate change. The goal of this study is to assess the heat resistance of different bumblebee species in field lab with a new experimental device to predict consequences of heat waves on the pollinator fauna.

The integrative taxonomy based on the unified species concept aims to overcome limitations due to unsettled efficiency of selected diagnostic traits and limited sampling. First, the approach considers multiple independent lines of evidence to evaluate inter-population differentiation processes and taxonomic statuses. This reduces the likelihood of false taxonomic conclusions driven by single trait. Second, analyzing multiple traits to investigate inter-population differentiation allows to increase the amount of information available despite a limited sample size. Here we investigated the potential taxonomic divergence between bumblebee populations from Arctic Fennoscandia and Alaska. We analyzed inter-population differentiation through multiple diagnostic traits: (i) a mtDNA marker (Cytochrome oxydase I, COI), (ii) a nuDNA marker (Phosphoenolpyruvate carboxykinase, PEPCK), and (iii) eco-chemical traits.

Moisture content effects of Normalized Difference Vegetation Index and photosynthesis rates in four low Arctic moss communities

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Climate change is expected to alter precipitation rates and patterns in Arctic regions and influence vegetation community patterns. Moss constitutes much of the understory in arctic vegetation communities and has been documented to change reflectance in response to even small variations in moisture. Here we investigated the role of moisture content on normalized difference vegetation index (NDVI) and photosynthesis of four sphagnum and pleurocarpus moss community types. Blocks of moss (20cm x 20cm) were collected near Imnaviat Creek, Alaska, saturated to full water capacity for 4 hours, and then allowed to air dry in the Toolik Lake Field Station incubation facility for 84 hours before being re-saturated. Peak photosynthesis for all community types (-1.311 to -2.081 $\mu mol/m^{-1}/s^{-1}$) occurred at 80% moisture content and declined significantly as moisture content decreased. Moss NDVI was significantly declined between 80% and 70% moisture content for sphagnum moss communities (-0.17 to -0.2) and less so for pleurocarpus communities (-0.06 to -0.12). Photosynthesis rates and NDVI values continued to decline until moss reached a steady weight (ecologically dry) over a period of 84 hours. Re-saturation caused NDVI to increase in both sphagnum (+0.18 to +0.23) and pleurocarpus (+0.10 to +0.17) in less than 15 minutes however only sphagnum communities showed photosynthesis rate (-0.824 $\mu mol/m^{-1}/s^{-1}$) increases after 24 hours. Despite NDVI values rebounding faster than photosynthesis rates after re-saturation, no community NDVI values or photosynthesis rates rebounded to values similar to those at time of initial saturation suggesting some physiological changes in each of the mosses. The difference in speed of changes in moss spectral values and photosynthesis with moisture content alterations indicates that NDVI as a sole proxy for productivity in Arctic vegetation communities may be problematic as a result of photosynthesis not recovering as quickly after dry periods.

Tundra fire disturbance homogonizes belowground food web structure, function and dynamics

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Increased lighting strikes on Alaska's North Slope since 2000 has occurrences of tundra fires are on the rise. On July 16, 2007 lightening ignited the Anaktuvuk River fire, burning a 40-by-10 mile swath of tundra about 24 miles north of Toolik Field Station. The fire burned 401 square miles, was visible from space, and released more than 2.3 million tons of carbon into the atmosphere. A large amount of the organic layer of the soil was burned, changing the over all composition of the site and exposing deeper soil horizons. Due to fundamental transitions in soil characteristics and vegetation we hypothesized that the below ground soil food web community would be affected both in terms of biomass and location within the soil profile. Microbial biomass was reduced with burn severity. In the lower organic layer there was a significant reduction in fungal biomass but we did not observe this effect in the upper organic soil. We did not observe a significant effect of burn severity on individual group biomass within higher trophic levels. Canonical Discriminant Analysis using the biomass estimates of the functional groups in the food webs found that the webs are becoming increasingly homogenized in the severe burn treatment compared to the moderate and unburned treatments. The greatest effects on food web structure at the lower organic depth, where the unburned treatment differed significantly from soils from both burn treatments.

We model the effects on soil organic matter processing rates and energy flow through the three webs. The model estimated a decrease in C and N mineralization with fire severity, due in large part to the loss of organic material. While the organic horizon at the unburned site had 12 times greater C and N mineralization than the mineral soils, we observed little to no difference in C and N mineralization between the organic and mineral soil horizons in the moderately and severely burned sites. The fire significantly altered the trophic structure of the soil food web, with loss of trophic complexity with increasing fire severity, which correlated strongly with food web stability.

A Pan-Arctic Synthesis of Cold Season CO_2 Emissions

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Over the past several decades, surface air temperatures in the Arctic have increased at approximately twice the global rate, and climate models project that this rate of warming will continue through the century, with the greatest warming occurring during the winter months. Carbon emissions during the cold season (i.e., fall, winter and spring) are an important component of annual respiratory loss, yet there are large uncertainties in local and regional estimates of cold season carbon emissions. To address these uncertainties, we conducted a pan-Arctic synthesis of cold season CO_2 emissions from northern high latitude terrestrial ecosystems. We compiled data from more than 70 studies from sites located throughout the permafrost region and examined differences in cold season respiration among permafrost zones, biomes, and ecosystem types. In 2016, we established ten automated winter respiration-monitoring sites across Alaska; preliminary results from those measurements will also be presented.

The synthesis results showed that cold season CO_2 emissions were positively related to mean annual air temperature, growing season precipitation, and Enhanced Vegetation Index (EVI). There were significant differences in CO_2 emissions among permafrost zones: CO_2 emissions were greatest in the sporadic zone compared to discontinuous and continuous zones, and were significantly lower in the continuous permafrost zone. Summarized results of experimental studies showed that cold season CO_2 emissions were significantly higher when soils were warmed and lower when vegetation was removed, demonstrating the sensitivity of carbon release to both rising temperatures and changes in vegetation cover in northern high latitudes. These results highlight the importance of including nongrowing season respiration in current and future carbon estimates for the northern region, and suggest that as winter temperatures increase across the Arctic, cold season CO_2 emissions may offset potential increases in plant productivity.

Applicability of the ecosystem type approach to model permafrost dynamics across the Alaska North Slope

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Thawing and freezing of Arctic soils is affected by many factors, with air temperature, vegetation, snow accumulation, and soil physical properties and soil moisture among the most important. We enhance the Geophysical Institute Permafrost Laboratory model and develop several high spatial resolution scenarios of changes in permafrost characteristics in the Alaskan Arctic in response to observed and projected climate change. The ground thermal properties of surface vegetation and soil column are up-scaled using the Ecosystems of Northern Alaska map and temperature data assimilation from the shallow boreholes across the Alaska North Slope. Soil temperature dynamics are simulated by solving the 1-D non-linear heat equation with phase change, while the snow temperature and thickness are simulated by considering the snow accumulation, compaction and melting processes. The model is verified by comparing with available active layer thickness at the Circumpolar Active Layer Monitoring sites, permafrost temperature and snow depth records from existing permafrost observatories in the North Slope region.

Monitoring phenology of Alaska tundra communities using the Mobile Instrumented Sensor Platform (MISP) system

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Understanding and monitoring environmental factors that influence phenology is important to understanding how climate change will alter Arctic plant communities. Here we detail yearly and intra-seasonal phenological shifts of vegetation communities in Toolik Lake, Imnaviat Creek, Atqasuk, and Barrow, Alaska. Monitoring was conducted on a 50m transect at each of the four study sites using the Mobile Instrumented Sensor Platform (MISP) system, with each transect traversing multiple community types. Normalized Difference Vegetation Index (NDVI) was measured using a mounted GreenSeeker system (Trimble Inc.) with near daily frequency during the growing seasons of 2012-2016. Thawing degree day (TDD) and soil thawing degree day (STDD) accumulation rates were the best predictors of peak NDVI values and the timing of those values for all of the communities, despite each site having its own unique weather patterns. During spring green-up and fall senescence, intra-seasonal patterns of daily NDVI changes were fairly steady, however extreme weather events (e.g. hard freezes and unusually warm days) had a punctuating effect on phenological changes causing NDVI shifts to increase for subsequent days. Dominant vegetation community types also responded differently and to varying degrees to environmental conditions and events. Determining the role that environmental factors play in inter- and intra-annual community phenology will help us to better understand the effects of climate change on Arctic terrestrial systems.

Survival of white spruce (*Picea glauca*) seedlings in subarctic Alaska under changing climate

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Alpine treelines in Alaska have advanced for the past 50 years in response to the recent climate warming. However, further increases in temperatures may cause treeline species drought stress and increase susceptibility to insect outbreaks and fire. Complex factors such as soil conditions and plant species composition also impact the survival of seedlings, which are essential to sustain boreal forests. Our goals were to assess 1) what environmental factors affect survival of treeline species, *Picea glauca* (white spruce) seedlings, 2) whether survival is different in season, and 3) if there are special or temporal effects on survival of the seedlings. We studied the survival strategies of spruce seedlings along an altitudinal gradient at 6 sites, consisting of tundra, forest, or transitional ecotone in Denali National Park and one forest site in Fairbanks, AK. In May 2012, four-month old seedlings were planted with or without naturally occurring plants to compare the presence or absence of the interspecific interaction. Summer temperatures were increased by one small greenhouse per site. After each summer growing seasons (June - August) and each winter times (September - May), survival rates were recorded, and the final survival was recorded at the end of the summer in 2014. Survival differed depending on treatments and seasons only for the first two years. Positive high temperature/summer effects at higher elevations were recorded, suggesting that treeline seedlings are expected to benefit warming climates. Oppositely, negative high temperature/summer effects at lower elevations could reduce survival of seedlings. Moreover, seedlings survived more in forests than in tundra, which indicates that mismatched environmental conditions in temperature, elevation and habitat type may not support seedlings to survive. Therefore, treelines may not advance as fast as it used to. Neighboring effects were not recorded obviously, in contrast to the significant results in biomass gains, suggesting that there could be a trade-off between survival and growth. Survival at each site were different and negative high temperature effects were pronounced; hence, further temperature increases may reduce seedlings, thereby reducing the population of *P. glauca* in the near future in this region.

NEON Aquatic Sampling and Infrastructure at Domain 18

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The National Ecological Observatory Network (NEON) is a national-scale research platform designed to assess the effects of climate change, land-use change, and invasive species on ecosystem structure and function across 20 ecoclimatic domains from Alaska to Puerto Rico. NEON's aquatic program is comprised of a suite of instrument and observational data collected at 24 wadeable streams, 7 lakes, and 3 large rivers, including biogeochemistry, hydrology, site morphology, and biology. Domain 18 aquatic sampling began at Oksrukuyik Creek and Toolik Lake during summer 2016. Initial sampling included collection of water and sediment chemistry samples, aquatic microbes, periphyton and phytoplankton, aquatic plants, macroinvertebrates, and zooplankton. Fish sampling will be initiated in 2017, as will construction of groundwater wells and sensor infrastructure, which will include continuously monitoring water quality sensors at both the stream and lake sites. Data collected by field technicians and returned from analytical facilities undergo automated quality assurance tests prior to being packaged and hosted on the NEON data portal. A subset of these data are expected to be available in 2017, providing opportunities to connect to a variety of supporting data streams, including LIDAR, atmospheric data, continuously monitoring sensors, and observational samples.

Closing the winter gap in permafrost carbon emissions: A passive, quasi-continuous $14CO_2$ sampler

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Over millennia, Artic soils have accumulated vast stocks of organic carbon in permafrost. A major concern today is that climate warming and permafrost thaw may result in the microbial decomposition and transfer of this carbon to the atmosphere. The potential magnitude, rate and timing of such permafrost carbon emissions, however, remain poorly quantified. Radiocarbon analysis ($14CO_2$) provides a unique tool for quantifying emissions of ancient carbon from thawing permafrost within ecosystem carbon fluxes. Advancing our understanding of permafrost carbon emissions urgently requires more continuous $14CO_2$ data, with the ability to capture emission pulses following precipitation events, freeze-thaw cycles, and during the winter. Here, we present first steps toward adopting a passive atmospheric $14CO_2$ sampler for deployment in arctic tundra. Initially, we are developing an inlet system that allows $14CO_2$ from air, snow and waterlogged or frozen soils to diffuse into an evacuated canister, that does not require heating. Ultimately, we will replace the canisters with molecular sieve traps to reduce the logistical burden. Our system will continuously trap the $14CO_2$ emitted from arctic tundra soils over several weeks year-round, and allow us to close the critical winter-gap in annual permafrost emissions.

Winter processes drive Arctic terrestrial carbon and water dynamics

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Our long-term studies in the Low and High Arctic provide a comparative framework to understand and quantify how winter snow traits have carry-over effects on biogeochemical and ecohydrologic processes such as plant mineral nutrition, plant water sources, CH_4 and CO_2 exchanges and culminate in ecosystem feedback process shifts.

Shifts in Phenology due to Climate Change: Physiological Plasticity in an Arctic Hibernator

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Shifts in the timing of seasonal events are among the most commonly reported responses of vertebrates to climate change. However, the mechanistic underpinnings of phenological shifts in hibernators are unclear and the potential for sex-dependent responses has not been examined. Here, we describe sex-dependent plasticity in the hibernation physiology of arctic ground squirrels in response to late spring snowstorms, which may be increasing under climate change. Female and non-reproductive male arctic ground squirrels responded to the >1month delay in snow melt by either extending hibernation or re-entering hibernation following several days of 'post-hibernation' euthermia. Reproductive males, in contrast, were not plastic and did not re-enter hibernation, presumably because high testosterone associated with seasonal gonadal recrudescence prevents torpor. Our results suggest that climate-driven delays in spring combined with differences in sex-dependent plasticity could lead to a seasonal mismatch between the sexes.

Shrub expansion, peat formation, and carbon sequestration in Arctic tundra on the North Slope of Alaska

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We present results from tundra soil profiles on the North Slope of Alaska to investigate responses of organic soil development, vegetation composition, and carbon (C) accumulation to climate change. Sedge peat initiated on mineral soils during the cold Little Ice Age, suggesting the critical importance of preservation of organic matter in initial peat buildup. The onset of Sphagnum peat occurred at ca. 1930 AD (n=6), likely caused by progressive soil drying in summers as a result of regional climate warming, earlier snowmelt and active layer thickening. Fossil pollen analysis shows that the expansion of dwarf birches since the early 2000s was preceded by willow increase since 1880 AD. Our results show that Sphagnum patches on this tussock tundra have been a sustained C sink, accumulating C at ~200 $gC/m^2/yr$ in the last two decades, in response to the recent accelerated Arctic warming. If Sphagnum patches expand on the tundra landscape in the future, the region could become an important net C sink of atmospheric CO_2.