Integrating Arctic Plant and Microbial Ecology - 21st ITEX meeting

ORAL PRESENTATIONS:

O1. Impacts of winter snow on plants and microbes in a mountain peatland

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Winter in the arctic and mid- and high latitude mountains are characterised by frost, snow and darkness. Ecosystem processes such as plant photosynthesis, nutrient uptake and microbial activities are therefore often thought to strongly slow down compared to summer. However, sufficient snow insulates and might enable temperature-limited processes to continue. Changes in winter precipitation may alter this, yet, winter ecosystem processes remain poorly understood.
We removed snow on an ombrotrophic bog in the Swiss Jura mountains to compare impacts and legacy effects on above- and belowground ecosystem processes. Snow in mid-winter (1m; February) and late-winter (0.4m; April) reduced the photosynthetic capacity (A_{max}) of *Eriophorum vaginatum* and the total microbial biomass compared to the subsequent spring (June) and summer (July) values. A_{max} of *Sphagnum magellanicum* and ^{15}N-uptake by vascular plants were, however, almost as high or higher in mid- and late-winter as in summer.
Snow removal enhanced freeze-thaw cycles and minimum soil temperatures. This strongly reduced most ecosystem processes in mid-winter compared to control and spring and summer values. Plant ^{15}N-uptake, A_{max} of *Eriophorum* and microbial biomass returned to or exceeded control values soon. However, *Sphagnum* A_{max} and length growth, and the microbial community structure showed carry-over effects of reduced winter snow into next summer. Our data indicate that peatlands are active in winter. However, a continuous snow cover is crucial for ecosystem processes both in winter and in the subsequent summer. Reduced snow thickness or duration due to climate change may impact on peatland ecosystem functioning at various levels.

O2. Long-term warming and increased snow depth alters richness and composition of taxonomic and functional groups of arctic fungi

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The arctic tundra is experiencing profound climate-induced changes, such as warming and precipitation increase, resulting in thawing permafrost, alterations in nutrient cycling and compositional shifts in plant communities. Fungi, including many plant symbionts and decomposers, likely have important, yet largely unknown, roles in current and future changes in arctic vegetation and nutrient cycling. We carried out deep DNA sequencing of soil samples to study the long-term effects of experimental summer warming (open top chambers, OTCs) and increased snow depth (snow fence) on fungal community composition in the dry heath and moist tussock tundra ITEX plots at Toolik Lake, Alaska. The results indicate that total fungal community composition responds strongly to summer warming in the moist tundra, but not in the dry tundra. On other hand, increased snow depth resulted in pronounced changes in both tundra types. Richness of ectomycorrhizal, ericoid mycorrhizal and lichenized fungi generally decreased, while saprotrophic, plant and animal pathogenic, and root endophytic fungi appeared to benefit from summer warming and increased snow depth. Several fungi belonging to the same functional guilds followed opposing trends that highlight the importance of species-specific responses to experimental manipulations. Also, the data indicate that many arctic fungi appear to be sensitive to changes in environmental conditions. In summary, responses of fungi to summer warming and increased snow depth appear to be dependent on tundra type as well as taxonomic identities. Therefore, we recommend an integrative approach to study arctic fungal ecology that takes into account fine-scale taxonomic assignments.

O3. Bacterial community composition in a subarctic peatland is resistant to experimental warming

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The historical status of northern peatlands as a carbon sink may be jeopardized by ongoing climate warming which is predicted to alter the relative magnitudes of organic matter production and decomposition. Given the key role of microorganisms in carbon and nutrient cycling in peatlands, it could be expected that shifts in microbial community composition are a sensitive indicator of changes in the biogeochemical status of these systems. In a long-term experiment in a sub-arctic peatland (at Abisko, Sweden), strong effects of climate manipulations via open top chambers (OTCs) on the magnitude of C and N-cycle fluxes have previously been observed. In this study we aimed to determine if these large warming impacts were reflected in corresponding changes in the composition of the soil bacterial community. We used Illumina sequencing of bacterial 16S rRNA genes and rRNA, replicated in space and time, and across four climate manipulation treatments. This design allowed us to partition variance between spatial heterogeneity, seasonality effects and the experimental climate-change treatments. Climate-treatment effects on soil processes were not associated with changes in the phylogenetic composition of the soil bacterial community. For both DNA- and RNA-based analyses, variation in community composition could be explained by the hierarchy: spatial variation (11 – 15 % of variance explained) > temporal variation (7 – 11 %) ≈ climate treatment (4 – 9%). This result suggests that the often presumed link between bacterial phylogenetic community structure and soil ecosystem function may not apply to generalized ecosystem functions such as soil organic matter cycling.

O4. Ectomycorrhizal fungi composition show resilience to experimentally increased snow depth in the High Arctic archipelago Svalbard

Pernille Bronken Eidesen, Sunil Mundra, Anna Vader, Elisabeth Cooper

Snow distribution due to wind and topography determine arctic vegetation composition at the local scale. Snow depth and feedback loops linked to vegetation, affect edaphic parameters and their soil-dwelling plant-symbionts such as mycorrhizal fungi. Shifts in symbiont guild can affect the fitness and reproductive output of the host plant, and *vice versa*. Direct effect of increased snow depth on the host plant, like shorter growing season, may for instance affect plant fitness and resource allocation (eg size of roots), which again can affect the carbon resources and physical space available for the symbionts. We investigated the effect of increased snow depth on diversity and composition of ectomycorrhizal (ECM) associations in a widespread arctic herb, *Bistorta vivipara* in two different vegetation types (Cassiope heath and mesic meadow) using an experimental set-up of snow fences and high throughput sequencing.. As ECM associations in *Bistorta vivipara* can be influenced by the amount of neighboring ECM plants, and the ECM guild differ among vegetation types, we expected an initial difference between vegetation types, and potentially different responses to snow manipulation. We found a clear differentiation among vegetation types, but weak response to six years of experimentally increased snow depth. Our data suggest that arctic ECM communities are resilient to short term variation in snow cover. However, changes may be expected in the long term, as vegetation composition eventually will change in response to altered snow cover, and ECM communities are structured by vegetation type.

O5 S. Richness and community structure of ectomycorhizal and saprotrophic soil fungi in relation to long-term experimentally increased snow in High-Arctic Svalbard

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Changing climate are expected to alter precipitation patterns in the Arctic with potential consequences for ecosystems, by affecting plant community composition and nutrient mobilization. However, the magnitude of detrimental effect of climate change remains unclear due to limited understanding of below-ground process. Here we addressed the effect of altered snow pattern on the richness and communities of soil ectomycorrhical (ECM) and saprotrophic fungi and their temporal succession. Within growing-season soil samples were collected nine times with 7-10 days intervals simultanously from deep-snow and ambient-snow plots. Fungal communities were determined using Illumina sequencing. ECM and saprotrophic richness decreased and increased in response to the deep-snow treatment, respectively and showed significant temporal variation (peak at Aug-16 and Sept-15, respectively) due to flctuation in temperature and precipitation conditions. Multivariate analysis revealed that snow-treatment and sampling dates have significant effect on saprotrophic, but not on ECM, fungal communities. Delayed snow-melt did not influence temporal succession of fungal community. Our results suggest that certain species become more abundant or locally extinct due to their vulnarability to climate fluctuation. Such compositional shifts might affect nutrient cycling and soil organic C storage.

O6. Interactions between fungal and shrub communities along a snow-depth gradient in NE Greenland

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Snow cover regime and length of the growing season are expected to continue to change in the Arctic in the coming decades, and this will markedly change the characteristics and functioning of plant communities. Shrub expansion represents one of the most dramatic change in the Arctic and is expected to cause major alterations in the diversity and composition of the co-occurring fungal communities. Fungi play central role in the functioning of terrestrial arctic ecosystems due to their activity as symbionts and decomposers, but it is poorly known how the ongoing changes in snow cover will affect the interaction between fungal and shrub communities. The aim of this study is to analyse changes in fungal community composition in three main dominant arctic shrub communities (snowbeds, heaths and fell-fields), which are associated with a decreasing mean snow-depth in winter, respectively. The study area was Zackenberg, NE Greenland. In each of these shrub communities soil samples were collected below contrasting plant patch types (*Salix arctica*, *Dryas octopetala* and moss). Soil fungi identification from soil samples was performed by Ion Torrent DNA-Pyrosequencing and bioinformatic analyses were done to describe the fungal communities. Our analyses reveal that it is fundamental to consider the interactions between fungal and shrub communities to properly predict the effects of varying snow regimes on terrestrial arctic ecosystems.

O7. Warming-induced tree expansion in the Arctic leads to a more closed N cycle

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Across the Arctic, ectomycorrhizal trees are expected to expand into current tundra as climate warms. This is thought to be linked to higher inorganic nutrient availabilities due to faster decomposition of organic matter. However, here we test the hypothesis that trees through their association with ectomycorrhizal fungi increase nutrient cycling directly from organic matter resulting in a more closed N cycle. We studied a subarctic-alpine ecotone from mountain birch forest to heath tundra and found a strong positive coupling between tree abundance and ectomycorrhizal fungal growth (ingrowth bags), both of which were negatively coupled with C sequestration. By 454-sequencing we identified a shift in dominance from root-associated ascomycetes in the heath to cord-forming ectomycorrhizal fungi in the forest. High C/N-ratios and low inorganic N levels in the forest humus suggest a more efficient mobilization of N from the soil, linked to higher activities of these ectomycorrhizal fungi. Further, bacterial-to-fungal biomass ratios and abundances of genes reflecting the size of denitrifier and bacterial ammonia oxidizing communities (qPCR) were lower in the forest. Together, our data suggest that the lower C sequestration rate in the forest, albeit higher litter inputs, is a consequence of a more efficient ectomycorrhizal N foraging from organic pools, which in turn restricts N cycling through inorganic pools.

O8. Bacterial community composition and potential for N-transformation processes in different tundra habitats

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Arctic tundra sites have experienced unprecedented shifts in vegetation composition, diversity and biomass in past decades attributed to climate warming. Changes in vegetation may have substantial impact on the belowground microbial communities and therefore on the biogeochemical processes and functioning of the Arctic ecosystems. Thus, prediction of these processes is at least in part dependent on knowing the structure and distribution as well as functional potential of the microbial communities in Arctic soils. This study investigates the effect of long-term warming-induced changes in vegetation on the microbial community composition and functional potential in soils from three sub-Arctic tundra habitats in northern Sweden: dry heath, meadow, and wet sedge. Results from the sequencing of 16S rRNA gene fragments, and the quantification of several N-cycle related genes showed that the bacterial community in heath soil is different from those in meadow and wet sedge. Soil C and N ratio, and moisture content had the strongest correlation with variation in bacterial community composition and the abundances of N-cycle genes. Warming had no effect on the bacterial community composition and the abundances of N-cycle genes in any of the habitats, but these parameters were different between the soil layers (organic or mineral) in heath and meadow soils. The abundances of several N-cycle genes related to denitrification and respiratory ammonification were more related to the bacterial community composition in the meadow and wet sedge soils than in the heath soil indicating genetic potential for different N transformation processes in these habitats. Our results suggest that soil properties are more important drivers of change in tundra soil bacterial communities than warming induced change in vegetation.

O9. Micro-scale heterogeneity buffers the effects of 20 years of experimental climate warming on soil mites in alpine/subarctic vegetation communities

Juha M. Alatalo and Peter Ľuptáčik

We studied the impact of 19 and 21 years of experimental warming, site and micro-scale spatial heterogeneity on soil mite communities in three contrasting plant communities in alpine/subarctic Sweden. Long-term warming and site had no significant effect. Instead, we found that micro-scale heterogeneity was the main controlling factor for soil mites in this severe environment. The results indicate that small-scale heterogeneity is most likely very important for buffering global warming for soil mites, so soil structure will be an important determinant of the potential impact of future global warming on soil fauna. The results also contradict the suggestion that short-lived species are more sensitive than larger, long-lived organisms to global warming by showing that small, relatively short-lived species can be very resistant to long-term warming.

O10. Survival of rapidly fluctuating natural low winter temperatures by High Arctic microarthropods

Stephen J. Coulson & P. Convey

Associated authors: Abbandonato, H.D.A., Bergan, F., Beumer, L.T., Biersma, E.M., Bråthen, V.S., D'Imperio, L., Jensen, C.K., Nilsen, S., Paquin, K., Stenkewitz, U., Svoen, M.E., Winkler, J. Course leader: Müller, E.

The climate of the Arctic – especially in the winter period - is changing. Winter temperatures are seen to be warming. Rain-on-snow (ROS) events are projected to increase in frequency and extent. Changes in snow lie, depth and period will follow. These changing conditions will have consequences for the successful overwintering of microarthropods. A field overwintering experiment to assess the effect of snow depth on winter survival of microarthropods in the High Arctic was performed as part of the AB:329 Arctic Winter Ecology course at the University Centre in Svalbard (UNIS, Longyearbyen) in the winter of 2012-13 and repeated in during the subsequent course in 2014-15. Soil samples were collected in September and placed out at locations where maximum snow depths of c. 0, 30 and 120cm were known to occur. An incubator treatment simulated frequent freeze-thaw cycling. The temperature of soil with no snow cover closely tracked that of the air. Minimum temperatures approached -30°C and there were large and rapid fluctuations. Soil temperatures under the deepest snow cover remained stable and constant at between 0 and -3°C throughout the winter. Contrary to expectations, there were no clear differences between the various thermal regimes in the overwintering survival of the microarthropod fauna. These results indicate a tolerance, previously undocumented for the Araneae, Nematocera or Coleoptera, of both direct exposure to at least -24°C and rapid and large temperature fluctuations. In conclusion, High Arctic microarthropod faunas may be robust to at least certain of the projected changes in Arctic winter climates.

O11. Long-term change in water chemistry and phytoplankton/invertebrate communities in Swedish arctic/alpine lakes

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Northern Scandinavian lakes are among the most remote lakes in Europe. Still these lakes are subjected to climate change and deposition of long-range air pollutants. We analyzed decadal trends for eight Swedish Arctic/Alpine lakes (1988–present) and found marked changes in several water chemistry variables and in the biodiversity of litoral invertebrates and phytoplankton. For example, all lakes showed drastic declines in total phosphorus concentrations and marked increases in pH. Also, many lakes showed declining sulphate concentrations, except those at very high elevations where sulphate concentrations instead rapidly increased since the mid-1990s. Beta-diversity of littoral benthic invertebrates declined over time, suggesting that communities became more similar over time. Beta-diversity for phytoplankton communities was stable over time. NMDS for both benthic invertebrates and phytoplankton ordered lakes by altitude (i.e. climate), indicating this was an important forcing function. Alpha diversity of benthic invertebrates, i.e. richness and EPT(taxa), showed significant increases in several of the lakes, illustrating the northward migration of species. The study shows the ongoing change in Arctic freshwaters and identifies water chemistry variables are useful early-warning indicators.

O12 S. Ecological responses of non-sorted circles tundra to simulated winter climate change

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Cryoturbated soils store large amounts of organic carbon globally. They result from soil particle movements and organic matter burial due to repeated freeze-thaw events. Non-sorted circles are a common cryoturbation feature throughout arctic and alpine permafrost areas. They are soil patches with sparse vascular plant cover (inner domain), surrounded by denser tundra vegetation (outer domain). Climate change will likely result in a deeper snow cover in large parts of the Arctic. Due to its good thermal insulation, deeper snow will likely affect soil freezing intensity and freeze-thaw cycles, with possible impacts on cryoturbation and ecosystem processes. We investigated ecological responses to experimental winter climate change at a subarctic alpine tundra harboring non-sorted circles (Suorooaivi, Sweden, 68.30N; 19.11E, 860m a.s.l.). We subjected the site to increased winter insulation for three consecutive years, through snow addition with fences or direct insulation with fiber cloth. Vegetation, soil fauna and microorganisms play important roles in the input and decomposition of soil organic carbon. We hypothesize that they will be affected both directly through higher winter temperatures, and indirectly by a decrease in cryoturbation. We expect increased plant growth, especially in the inner domain, resulting in alterations in soil fauna and bacterial communities. Insulation manipulations increased surface soil temperatures, especially daily minimum temperatures, and altered freeze-thaw cycles. We will also present how CO_2 fluxes, plant growth, soil fauna and bacterial communities were affected by the effects of increased winter insulation. Finally, we will discuss the impacts of alterations of these components and their mutual interactions.

O13 S. Emission of biogenic volatile organic compounds from arctic ecosystems- responses to climate manipulations

Frida Lindwall

Biogenic volatile organic compounds (BVOCs) are produced and emitted from all living organisms. They are very reactive, forming a link between the biosphere, atmosphere and climate. The emission of BVOCs from tundra ecosystems has been predicted in global models to be close to zero. However, field measurements have shown much higher emissions rates than was has been estimated from models. I suggest that a large discrepancy between surface and air temperature, due to the low albedo of the tundra, makes it impossible to model the temperature dependent BVOC emissions from the arctic on the basis of air temperature. It has been estimated that the global BVOC emissions will increase by 30-45% due to 2-3°C rise in temperature. Increased emissions could lead to a longer lifetime of methane in the atmosphere, but may also lead to an increased formation of aerosols. I will present very new data on responses in BVOC emissions from field experiments in the high, low and subarctic ecosystems in ambient conditions and under climate manipulations. The arctic is getting warmer and the ecosystem BVOC emissions respond very strongly to rising temperatures, much stronger than the global mean. Thus, I suggest that Arctic BVOC emissions will be of higher importance in a future warmer climate. I will also show how BVOC emissions vary over a 24-hour period, suggesting taking night-time emissions into account when studying BVOC emissions from arctic ecosystems.

O14. The Diapir Divorce in Deserts: soil diapirs provide nutrients to plants but diapirs don't explain soil activities

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Polar deserts contain sparse plant communities but respire CO_2, CH_4 and N_2O at rates comparable to other Arctic ecosystems. The contradiction between high soil activity and low plant productivity led us to hypothesize that these deserts may contain 'pockets' of active soil. We think that diapirs may be one such pocket. Elevated nutrients in diapirs would be used by plants and also would explain how these deserts are respiring at elevated rates. We assessed nutrient cycling in diapirs in two polar semi-deserts over the spring, summer and fall of 2013 at Alexandra Fjord Dome. We assessed the soil respiration, nitrogen mineralization, nitrification as well as the natural abundance of nitrogen present in the soil profile and associated plant species. We also assessed $^{15}NO_3$, $^{15}NH_3$ as well as $P^{18}O_4$, uptake into the plant and microbial community. Unexpectedly diapir soils did not have higher soil respiration of CO_2, CH_4 or N_2O but did have elevated soil organic matter content. Furthermore, the diapir effect on nitrogen cycling differed strongly between the soils. In the alkaline desert, diapirs increased mineralization and nitrification but in acidic deserts, diapirs reduced these processes. Thus, our initial idea that the diapirs were 'pockets' of soil activity was not supported by the data. Instead, it appears that diapirs have increased carbon but reduced respiration, and altered nitrogen cycling. However, ^{15}N natural abundance indicated that diapir nitrogen was acting as a strong source for plants. The puzzle of the Dome deserts remains. Somehow, the coupling between soil nutrient stores and respiration is broken, but the link between palnts and soil remains.

O15 S. Putting Carbon in the Pocket of Polar Deserts: Plants and Organic Carbon in Desert Frost Boils

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Polar deserts make up approximately 25% of the ice-free Arctic. These barren landscapes are typically thought to contain little soil organic carbon (SOC); however, recent work on high Arctic landscapes suggests SOC in deserts may be grossly underestimated. Diapirs form when parent material above the permafrost table is heaved upwards in the centre of frost boils. Soil organic matter accumulates on diapir features forming a Bhy soil horizon. We hypothesized that subsurface SOC associated with diapirs would be reflected in surface vegetation or alternatively, explain increased sub-surface carbon storage in polar deserts. We used a field-portable visible and near-infrared (vis-NIR) spectrophotometer to detect SOC in the subsurface soil profile of 559 frost boil centres at the acidic and alkaline deserts at Dome, Alexandra Fiord. We also assessed fine-scale SOC distribution (n= 24) and plant community (n= 52) on frost boils. As expected, we detected SOC enrichments at depth indicative of diapirs features and these diapirs occurred on approximately 17% of frost boils. The distribution of SOC within the fine scale grids was extremely variable and differed between frost boils regardless of diapir presence or absence. Further, plant community richness and diversity were not strongly linked to diapir presence. We interpret this to imply that plant communities may be influencing diapirs via a top-down process such as root exudate release. Diapirs, in turn, may not be a dominant influence on plant community composition. Despite this, it appears that diapirs are relatively common in these deserts and are indeed pockets of SOC in the deserts.

O16. How do different soil characteristics and climate influence tundra shrub growth in Alaska?

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The greening of the Arctic is one of the best documented recent trends in the terrestrial Arctic. A part of this greening has been attributed to an increased shrub cover. On the Alaskan North Slope, some shrub patches have increased rapidly (expanding), while others have increased little or not at all (stable) within the last 50 years as shown by repeat photography. Dendroecological sampling of expanding and stable shrub patches was conducted in the treeless tundra of the North Slope foothills in Alaska. Shrub patches were located on river slopes and consisted of 0.5 to 3 m tall alder, willow and birch shrubs. We also measured soil temperature, soil moisture, soil carbon and nitrogen content, thaw depth, pH and C/N values in shrub leaves. We investigated the influence of the soil characteristics on the ring width of the last year of growth with generalized linear models and the influence of climatic factors with correlation and regression techniques.
All three species showed consistently stronger annual radial growth in expanding patches compared to stagnant ones. The recent radial growth trend of shrubs in expanding alder and willow patches has been increasing; the growth trend of shrubs in birch patches has been decreasing, irrelevant of their assignment to the expanding/stable category. Shrubs in expanding shrub patches had significant positive correlations to summer and spring warming. Our analyses indicate that thaw depth and soil temperature are the main soil factors influencing the magnitude of shrub ring formation.

O17. Could shrubification threaten soil carbon stocks in the Arctic?

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The 'shrubification' of the tundra biome is now a hot research topic, and the term itself has been proposed as a new word in the Collins Dictionary. Increases in the cover, abundance and/or biomass of shrubs, particularly in Arctic tundra, are associated with changes in snow depth and duration, surface energy budget and roughness, and alterations in ecosystem carbon fluxes and storage. Understanding the causes and consequences of shrubification has become a major focus for global change scientists, but what we measure above-ground is only the tip of the metaphorical iceberg.

In this paper we consider the implications of shrubification for processes in the rhizosphere, including the likely key role of mycorrhizal symbionts for carbon allocation and soil organic matter dynamics. We present recent data from experiments conducted around the sub-Arctic forest/tundra heath ecotone near Abisko, Sweden, and at a low Arctic tundra site in the Mackenzie Uplands of Northwest Territories, Canada. Measurements of plant and soil processes at both sites, deploying techniques ranging from ^{13}C pulse-labelling, to the use of vegetation and soil transplants across ecotones, provide some tantalizing indications that more productive ecosystems may not necessarily sequester more carbon from the atmosphere. Is the role of mycorrhizas pivotal for ecosystem carbon budgets, and could a little bit of 'greening' in the Arctic result in a lot of carbon loss to the atmosphere?

O18 S. Limited Effects of a Decade of Warming on Tundra Vegetation in a Svalbard Mesic Meadow

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While manipulative warming experiments have detected significant changes to alpine and arctic ecosystems, the nature of these changes appear to vary significantly in space (i.e., regionally and at the neighborhood level) and time (i.e., short- versus long-term effects). Although a substantial number of experiments have been performed in arctic tundra, relatively few have taken place in the high Arctic and even fewer of these have been long-term studies. As a result, many trends from low Arctic and subarctic systems have been discussed in relation to higher latitude tundra. To understand climate change effects on high Arctic vegetation, we measured the responses of a Svalbard meadow community to 12 growing seasons of open-top chamber (OTC) warming. There was no significant difference in the abundance of living vascular plant material, contrary to many other tundra experiments, although there was a significant, sometimes threefold increase in dead plant material in warmed plots. Abundance shifts of dead biomass are likely important given the strong linkages between community productivity, litter accumulation and decomposition, and nutrient and carbon cycling. We also found subtle shifts in functional group composition: forbs and rushes expanded in cover in warmed plots at the expense of the dominant shrub, *Salix polaris*. Surprisingly, there were few effects of warming on community diversity or evenness at any site, although individual species showed various responses to warming, from positive to negative effects on abundance, growth, and reproduction. Changes to community composition and effects on individual populations must be assessed at a local scale in order to draw reliable conclusions about the future trajectories of these communities.

O19. Leaf traits and canopy structure in heterogeneous arctic vegetation

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Throughout the Arctic, the photosynthesis and overall CO_2 exchange of whole tundra vegetation canopies can be predicted with useful accuracy knowing only air temperature, incoming light, and either total leaf area or total canopy nitrogen content. This predictability at the canopy level occurs despite the well-known heterogeneity and patchiness in species composition of Arctic vegetation, and despite a wide range of variation among species and plant functional types in leaf-level properties. To explain this apparent contradiction between predictability at the canopy level and variability at the leaf level, we described within-canopy variation in the light environment, leaf display, nitrogen distribution, and leaf properties in tall deciduous shrub vegetation, dominated by either *Betula nana* or *Salix pulchra,* near Toolik Lake, Alaska. Whole canopies dominated by either species showed the expected total leaf area-foliar nitrogen relationships but differed in the vertical distribution of leaf area, leaf nitrogen, and individual leaf traits such as specific leaf area, N concentration, and N mass per unit area. The convergence of overall canopy properties results from the optimization of the distribution of these multiple, interacting leaf traits; each species has a different solution.

O20. Relative flowering time helps explain climate sensitivity of Arctic and alpine plant phenology

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The phenology of vegetation in tundra regions is strongly affected by temperature, and thus is predicted to be particularly sensitive to climate warming. Previous studies have found that Arctic and alpine plants advance phenological events in response to warmer temperatures. However, responses differ between lifeforms, species, and locations, with some plants shifting phenological events more than others. Identifying the underlying mechanisms for the varied phenological responses of tundra plants is integral for predicting how vegetation will respond to climate change in the future. To identify factors that affect changes in tundra plant phenology at a global scale, we analyzed phenological responses of over 147 species at 20 sites from Arctic and alpine ecosystems around the world. We analyzed data from both long-term monitoring plots and warming experiments. We predicted that plants which flower later in the season would advance phenology more with warmer temperatures than early-flowering species. Phenology of late-flowering species may be more responsive to cumulative heat sums over the growing season, whereas phenology of early-flowering species probably depends more on timing of snowmelt. Preliminary results supported our predictions: the phenology of late-flowering tundra plants was more sensitive to summer temperature change than the phenology of early-flowering species. These divergent responses of late versus early-flowering species led to shorter community-level flowering seasons in warmer years. Our results suggest that the relative flowering time of plants can help predict phenological changes of species and plant communities across tundra ecosystems in response to climate warming.

O21 S. Subarctic plant phenology along a microclimatic gradient

Friederike Gehrmann

In mountain ecosystems, topography varies on a small scale and creates natural abiotic gradients, for example in the timing of snowmelt, the temperature and soil moisture. The length of the growing season for plants is primarily controlled by the timing of snowmelt in high latitudes as it determines the temperature and the quality and quantity of light reaching the plants. We present results on the vegetative and reproductive phenology of dwarf shrubs growing above the treeline in subarctic Kilpisjärvi, Finland, in relation to these microclimatic factors. The timing of snowmelt varied by up to 1.5 months between microhabitats and influenced the timing of phenological events. In *Betula nana*, vegetative phenology was significantly delayed when snowmelt occurred later. The fruit set in *Empetrum nigrum* required significantly more days for plants growing on a North-facing slope. The speed of development was also affected by the microhabitat conditions. The results suggest that subarctic dwarf shrubs differ in the degree of phenological variation. Some have a more conserved phenology across populations while others exhibit adaptation and/or acclimation to the local environment. This observation is ecologically significant when considering the effect of climate change on plant development. Species with a broader range of responses to current variations in their habitats are more likely to cope with climatic stress than those with a narrow range.

O22. Plant phenological responses to a long-term experimental extension of growing season and soil warming in the tussock tundra of Alaska

(Presented by J. May)

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Climate warming is strongly altering the timing of season initiation and season length in the Arctic. Phenological activities are among the most sensitive plant responses to climate change and have important effects at all levels within the ecosystem. We tested the effects of two experimental treatments, extended growing season via snow removal and extended growing season combined with soil warming, on plant phenology in tussock tundra in Alaska from 1995 through 2003. We specifically monitored the responses of eight species, representing four growth forms: 1) graminoids (*Carex bigellowii* and *Eriophorum vaginatum*); 2) evergreen shrubs (*Ledum palustre*, *Cassiope tetragona*, and *Vaccinium vitis-idaea*); 3) deciduous shrubs (*Betula nana* and *Salix pulchra*); and 4) forbs (*Polygonum bistorta*). We examined three phenophases: leaf bud break, flowering, and leaf senescence. Our study answered three questions: 1) Do experimental treatments affect the timing of leaf bud break, flowering, and leaf senescence?; 2) Are responses to treatments species-specific?; and 3) Which environmental factors best predict timing of phenophases? Treatment significantly affected the timing of all three phenophases, although the two experimental treatments did not differ from each other. While phenological events began earlier in the experimental plots relative to the controls, duration of phenophases did not increase. Treatment did not affect total length of the active period, as defined from bud break to leaf senescence. The evergreen shrub, *Cassiope tetragona*, did not respond to either experimental treatment. While the other species did respond to experimental treatments, the total active period for these species did not increase relative to the control. Air temperature was consistently the best predictor of phenology. However, different abiotic variables had varying degrees of importance throughout the growing season. Our results imply that some evergreen shrubs (i.e. *C. tetragona*) will not capitalize on earlier favorable growing conditions, putting them at a competitive disadvantage relative to phenotypically plastic deciduous shrubs. Our findings also suggest that an early onset of the growing season as result of decreased snow cover will not necessarily result in greater tundra productivity.

O23. Patterns in plant functional traits across the tundra biome over space and time

Anne D. Björkman, Isla Myers-Smith, Sarah Elmendorf, the sTUNDRA and ITEX working groups and the Tundra Trait Team

Identifying and understanding large-scale patterns in functional traits can help us predict they future responses of plant communities to climate warming. However, nearly all investigations of biogeographic patterns in plant traits stop at the northernmost extent of the temperate zone, and do not extend into the tundra biome. We investigate how canopy, leaf, and wood traits vary along climate gradients in the ecosystems beyond the latitudinal and elevational treeline by combining a large tundra vegetation change dataset with trait data from the TRY plant trait database. We explore patterns in both among-species (community mean) trait variation and within-species trait variation. We additionally assess the change in community weighted trait values over time. We find that the community trait values associated with resource acquisition are greater in warmer sites, while conservative trait values are disproportionately found in colder sites across the tundra biome. Community mean trait values also changed significantly over two decades of warming in a direction consistent with existing geographic patterns. By exploring biogeographic patterns in plant trait distributions across space and over time we can better understand how tundra plants might respond to a warming climate and the consequences of these changes for ecosystem function.

O24. Impact of snow and temperature on alpine plant phenology in the Alps

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In alpine environments, the growing season is severely constrained by low temperature, snow and frosts. The timing of vegetation onset in spring is critical for survival, growth, reproductive success and competitive abilities. Assessing the effect of climate change on alpine plant phenology requires a good understanding of the direct or indirect impact of the snow cover and air temperature.We analyze the climatic data from 74 automatic snow and meteorological stations that contain almost 20 years of data in alpine terrain ranging from 1600 to 3000 m asl in the Swiss Alps. The network gives a unique opportunity to analyze snow and climate effects on timing and growth of alpine vegetation because the ultrasonic sensor mounted in each weather station detects plant growth in summer (beginning of growing season, plant height). Our analysis of trends over time indicates that the timing of snowmelt and the beginning of plant growth were tightly linked over the past 20 years. We also detected trends towards earlier maximum plant height, highly correlated with above-ground biomass. Combining data from meteorological stations with phenology data gave us novel insights in phenological changes in alpine terrain over time and mechanisms influencing plant phenology.

O25. Temperature and precipitation effects on alpine plant communities. Results from a transplant experiment in southern Norway

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Climate change affects arctic and alpine plant community composition and function. Both experimental and observational studies document pervasive change, but also inconsistencies in the rates and direction of change in these systems. Such inconsistencies challenge our understanding of the underlying processes as well as our abilities to predict future community and functional trajectories. Variation in precipitation regimes has been implicated as a potential explanation of these inconsistencies, but the data is inconclusive, and as precipitation itself is also predicted to change, we need approaches that allow investigation of the interactive effects of temperature and precipitation change. To tackle these challenges, we set up a climate grid consisting of three levels of temperature (tetraterm 7.5, 9.5, 11.5°C) and four levels of precipitation (annual precipitation 700, 1500, 2300 and 3000 mm) in southern Norway. We carried out a factorial transplant experiment where turfs with intact plant communities were transplanted towards warmer and wetter climates, paralleling the climate change projections in our study region. The experiment was initiated in 2009, and has been monitored for four years. Temperature and precipitation responses are non-additive, and the communities generally respond faster to temperature than to precipitation change. After four years, however, the response to precipitation change is comparable to, and in some cases exceeding the temperature response. Our results suggest that both environmental sorting and biotic interactions are important in determining species’ fates, and that these processes vary along broad-scale climatic gradients and with the specific climatic change scenario the community is subjected to.

O26. Maintaining long-term climate data at ITEX sites: results, problems and solutions from Alexandra Fiord since 1989

Greg Henry, Anne Bjorkman, Cassandra Elphinestone, Esther Frei, Claude Labine

The major objective of ITEX research is to understand the response of tundra systems to climate variability and change; with the change either imposed experimentally or naturally over time. Hence, most ITEX sites have had some type of climate monitoring at the site and/or in the plots which have been maintained over time. However, most researchers in ITEX are ecologists and not climatologists, and are perhaps not as fastidious about measurements as a micro-climatologist may be. Maintaining a quality climate record requires proper maintenance of the stations and instruments used and deterioration of the accuracy or resolution over time can be a problem. Here we critically assess the long-term climate record from stations and the ITEX plots at Alexandra Fiord, some of which were established in 1989. In particular, we focus on the problems of detecting signals in seasonal air and soil temperatures, and snow depth. Temperatures have and continue to increase, and the effect of the OTCs is maintained over time, although with annual variability and considerable gaps in some records because of thermocouple deterioration and data logger malfunctions. Snow depth has been measured relatively continuously with range sensors in the experimental plots, and while there appears to have been an increase in snow depth over time, gaps in the record make the interpretation difficult. These issues impact the ability to link plant variables with climate changes, but despite the problems in this particular long-term data set, it appears the signal is stronger than the noise.

O27. Does quantitative trait differentiation in Arctic tundra species facilitate adaptation to climate change?

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Rising temperatures under climate change are expected to cause poleward migration of plant populations. Established local populations, however, might end up being maladapted if they lack phenotypic plasticity, which would allow them to adapt to changing environmental conditions. In this context, gene flow between southern populations and populations at higher latitudes might provide a source of genetic material pre-adapted to warmer temperatures. However, lacking adaptation to non-climatic environmental conditions – for example photoperiod, biotic interactions, or edaphic conditions – might hinder the establishment of immigrating southern populations. In 2011, we transplanted individuals raised from seeds from several southern and local populations of three Arctic tundra plant species into warmed (OTC) and control plots at Alexandra Fiord, Ellesmere Island, Canada. With this set-up, we aim to test whether local populations will be able to adapt and survive or whether they will be replaced by immigrating southern populations at High Arctic sites under a future warmer climate. Phenology and growth measurements during three growing seasons showed that warming alone does not facilitate success of southern populations at northern latitudes. Here, we determine trait heritability and quantitative genetic differentiation among populations (Q_{ST}) of these traits. This allows us to evaluate whether migrating southern populations could provide additional genetic diversity, which might enhance the adaptive potential of local populations.

O28. Climate change in the Arctic and the response of locally adapted populations.

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Fetcher and Shaver proposed in 1990 that ecotypic differentiation in Arctic plants could affect primary productivity. Data from a six-way reciprocal transplant experiment with *Eriophorum vaginatum* in Alaska showed that ecotypes were genetically specialized to local conditions. Ecotypes from sites with colder temperatures were less capable of responding to an increase in temperature than ecotypes from warmer regions. As the Arctic climate warms, the optimal environment for *E. vaginatum* may be physically displaced from the local population, unless dispersal or *in situ* evolution keeps pace, resulting in a phenomenon called adaptational lag. Both tiller population growth rates and 17-year survival rates suggest that that climate optimum for performance of *E. vaginatum* is displaced ca. 140 km northwards from the home sites. In the coming decades, the predicted course of warming in the Arctic should provide multiple tests for the hypothesis of adaptational lag and its consequences for primary productivity. If it is supported, the effect of climate change on Arctic plant communities may be much less predictable than would be the case for plant populations that are not differentiated into ecotypes.

O29. Trends in snow melting and leaf senescence and their impacts on the growing season length of high elevation alpine plants.

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Changes of leaf senescence may play an important role in extending the growing season length, especially in combination with changes of spring snow melting. Here we analyze the patterns of spring snow melting, leaf senescence and growing season length over eight years of monitoring (2007-2014) in a high elevation site above the treeline in the Italian Central Alps. We selected 49 plots, 17 target species of the subalpine and alpine belts and two main growth forms (graminoids vs. forbs). The phenological measurements were carried out according to the ITEX protocol with measurements every 2-3 days from the spring snowmelt to the beginning of the permanent snow cover in Fall. Climatic data were provided by the La Foppa AWS (ArpaLombardia), located at 2700 m at less than 1 km far from our site. At inter-specific level both snow melting and leaf senescence showed high inter-annual variability. Graminoids exhibited earlier spring snow melting (13.5 days), leaf senescence (4 days) and longer growing season (9.5 days) than forbs. The differences between graminoids and forbs were statistically significant (Wilcoxon test) for snow melting ($p<0.05$), but not for leaf senescence ($p>0.05$). The most important environmental factors influencing leaf senescence were spring snowmelt date, July thawing degree days (TDD), growing season TDD, July rain and photoperiod. Since 2007 leaf senescence exhibited a slight delay (0.4 d/y, $p<0.05$) at inter-specific level, while at intra-specific level, half species advanced up to 2 days/year while the other delayed up to almost 4 days/year. Concerning the trends of leaf senescence since 2007, the inter-specific trend shows a slight delay of 0.4 days/year ($p<0.05$). At intra-specific level, half species advanced up to 2 days/year, while the others delayed up to almost 4 days/year.

O30. Making sense of two decades of vegetation change at Barrow and Atqasuk

Robert Hollister et al.

The ITEX sites at Barrow and Atqasuk were established in the mid 90's. The four sites include a wet and a dry community at each location. We have monitored all common species at each site. We have documented a general increase in growth and earlier flowering of some species at the sites and with warming. Plant phenological and growth responses to warming have diminished in recent years, this is due to it being warmer in recent years and the response to warming being less in a warmer year. In fact, the response to warming has been relatively constant over time when you account for seasonal temperature. We have documented a general increase in shrubs and graminoids and a decrease in lichens across the sites. However most changes are not directional. Annual point framing of adjacent sites show large changes in plant cover between years. This variability between years likely explains the lack of directionality and the poor correspondence between changes in species growth and cover.

O31. Phylogenetic community structure determines the responsiveness of tundra plant communities to climate warming

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Mounting evidence show that arctic and alpine landscapes are undergoing distinct changes in plant community structure, presumably as a consequence of changing climate. However, most studies assessing these changes have used relatively simplistic measures of community structure, notably plant functional types (PFTs), species counts, and/or species turnover. Here we assess the effects of climate warming on the dynamics of plant phylogenetic community structure (PCS) across a set of different tundra plant communities in sub-arctic Sweden. We sequenced the plastid markers *matK* and *rcbL* for the 75 plant species found in the five plant communities at the alpine Latnjajaure Field Station and calculated the α-PCS measured as net relatedness index. Preliminary results indicate that in response to warming, the PCS of a local community with high phylogenetic diversity (or phylogenetically over-dispersed communities) decreased by one fourth. In contrast, a local community with low phylogenetic diversity (or one that is phylogenetically clustered) did not respond to climate warming. Thus, these preliminary results suggest that in phylogenetically diverse local communities, climate warming causes a selection for species that share the traits to respond to this new selective pressure. This, in turn, leads to a community that comprises more closely related taxa. As more reliable phylogenetic hypotheses have become available for many organism groups in recent years, approaches to integrate phylogenetic information into studies of phylogenetic community structure now allow circumpolar synthesis to move beyond the simplistic PFT concept and address changes at the very species level.

O32 S. The long term response of *Salix rotundifolia* to experimental warming

Ashley E. Brecken and Robert D. Hollister, Grand Valley State University

Climate change is a rising concern in the scientific community that affects the polar regions of the earth more and at a faster rate than any other region. Changing tundra conditions could have global repercussions, and arctic plants are a critical part of the delicate landscape. This study examines the response of the deciduous shrub *Salix rotundifolia* to nearly two decades of experimental warming. The number of inflorescences, the leaf length, and the inflorescence height have been analyzed, along with phenology data, from 2010 to 2014. The inflorescence height and leaf length are longer, while there are fewer inflorescences in warmed plots than in control plots. The differences between warmed and control plots characterize the response *Salix rotundifolia* would have to climate change and suggest that the plant has become larger and has focused its resources on fewer larger flowers. Other studies show that the cover of the plant has also decreased with experimental warming. Together, these findings suggest that the plant will do poorly in the future with climate change.

O33. Comparison of using handheld and Mobile Instrumented Sensor Platform NDVI measurements to track associated plant activity period at Toolik Lake, Alaska ITEX site

Jeremy L. May and Steven F. Oberbauer

High-frequency manual field measurements of plant and ecosystem properties are often time consuming and cost prohibitive in long-term ecological studies. One approach to address this problem is to use electromechanical devices, such as mobile instrumented sensor platforms (MISPs) to partially or fully automate the process. The objective of this study was to monitor normalized difference vegetation index (NDVI) at a low arctic tundra site located near Toolik Lake, Alaska using MISP systems installed in close proximity to ITEX plots to compliment long-term vegetation monitoring protocols established by the ITEX program. Measurements of NDVI were made on a regular (near daily) basis during the 2015 growing season (June-August) using Trimble GreenSeeker RT100 NDVI sensors mounted on the MISP systems measuring 50m transects from an average height of 1m and using a handheld Trimble GreenSeeker NDVI sensor on established ITEX warmed and control plots. The ITEX site and established 50m transect each span a moisture gradient from dry heath to moist acidic tundra. We tracked NDVI measurements throughout the season to monitor variation in plant activity periods among community types to determine the effectiveness of the two measurement frequencies to capture peak seasonal greenness and late season senescence. High frequency NDVI measurements allow tracking of plant community properties of ITEX sites at fine temporal and spatial scales, as well as providing an accurate estimation of plant active period.

O34. Standardized measurements of herbivory within ITEX experimental sites: first trials

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Herbivory can mediate the responses of plants to warming, and herbivory itself can also be affected by increased temperatures. Thus, it is of upmost importance to measure the responses of plants to both warming and interactive effects of warming and herbivory. We designed a protocol that measures herbivory in warming experiments in a standardized way, so results are comparable across sites. We tested this protocol in the field during summer 2014 at 8 sites, 4 of them comprising ITEX manipulations. The protocol involved a site-level assessment (vertebrate herbivore activity quantified along transects) and a plot-level assessment (vertebrate and invertebrate herbivory quantified within the experimental plots using point intercepts).We will present the first results obtained with this protocol and discuss some improvements for future implementations in the field. Site-level assessments gave a broad context of vertebrate herbivore activity that was not captured by plot-level measurements. Plot-level assessments reflected mostly the activity of invertebrate herbivores and allowed comparison of the frequency of invertebrate leaf damage in plots subjected to long-term passive warming with un-manipulated control plots. Overall, the frequency of invertebrate herbivory in the control plots was low (~10%) and varied across sites, but was consistently greater in experimentally warmed plots, at nearly double the frequencies observed in control plots. How the increased levels of invertebrate herbivory in the long-term warmed plots may have influenced the responses of plants to warming deserves further research, and only coordinated efforts can help address these questions.

O35. Does experimental warming effect herbivory by leaf-chewing insects in an alpine plant community?

Tone Birkemoe, Saskia Bergmann, Toril E. Hasle og Kari Klanderud

Climate warming is predicted to affect species and trophic interactions worldwide, and alpine ecosystems are expected to be especially sensitive to changes. In the present study, we used two ongoing open-top chamber (OTC) experiments at Finse, Norway to examine if warming had an effect on herbivory by leaf-chewing insects in an alpine plant community. We recorded feeding damages on the most common vascular plant species in the OTCs and control plots at the two experimental sites and found that warming increased the relative herbivory pressure on *Dryas octopetala* and *Bistorta vivipara,* but not on *Salix reticulata*. These changes in feeding damages suggests that warming have caused changes in herbivore activity and possibly feeding preferences. The herbivore community consist primarily of Lepidoptera, with the mountain burnet *Zygaena exulans* as the most common species. We found no differences in the mountain burnets willingness to feed on *D. octopetala*, *B. vivipara* and *S. reticulata* in the laboratory.

O36. Mammalian herbivores confer resilience of Arctic shrub-dominated ecosystems to changing climate

Elina Kaarlejärvi, Katrine S. Hoset and Johan Olofsson

Climate warming is resulting in a rapid expansion of shrubs in the Arctic. This expansion is reinforced by positive feedbacks, and this vegetation change could thus set the ecosystem on a trajectory towards an alternate, more productive regime. Herbivores, on the other hand, are known to counteract the effects of simultaneous climate warming on shrub biomass. However, little is known about the impact of herbivores on resilience of these ecosystems, i.e. the capacity of a system to absorb disturbance and still remain in the same regime, retaining the same function, structure and feedbacks. Here we investigated how herbivores affect resilience of shrub-dominated systems to warming by studying the change of shrub biomass after a cessation of long-term experimental warming in a forest-tundra ecotone. As predicted, warming increased the biomass of shrubs, and in the absence of herbivores shrub biomass in tundra continued to increase four years after cessation of the artificial warming, indicating that positive effects of warming on plant growth may persist even over a subsequent colder period. Herbivores contributed to the resilience of these systems by returning them back to the original low-biomass regime in both forest and tundra habitats. These results support the prediction that higher shrub biomass triggers positive feedbacks on soil processes and microclimate, which enable maintaining the rapid shrub growth even in colder climates. Furthermore, the results show that in our system, herbivores facilitate the resilience of shrub-dominated ecosystems to climate warming.

O37 S. Shrub expansion in Scandinavian mountain range: the importance of grazing

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The warming of recent years has caused a shift in plant community structure in arctic areas and one of the most obvious changes is the expansion of shrubs. However, studies have found that reindeer can influence ecosystem responses to warming and inhibit shrub expansion. We revisited grazed (ambient) and ungrazed (fenced) study plots, at the southern as well as the northern limits of the Scandes mountain range, to investigate how the vegetation had changed in response to increasing temperatures between 1995 – 2011. The plots are situated in two vegetation types, dry heath and mountain birch forest, and we found that shrub cover had increased dramatically in both. At the dry heath sites low shrub cover had on average increased by 98% and tall shrubs by 168%. At the birch forest sites low and tall shrubs had increased by 169% and 85%, respectively. The effect of grazing was minor, with no significant differences in shrub cover observed between fenced and ambient plots. Neither were there any significant differences in species richness or Simpson's D. However, July soil temperatures were higher in ambient plots at five out of six sites, whereas mean January soil temperatures were higher in fenced plots at all the dry heath sites. Furthermore, NMDS ordinations showed indications of a divergence in community composition due to grazing. We conclude that shrub expansion is rampant in the Scandes mountain range. Herbivore influence appears to be smaller than expected, but compositional changes in response to grazing may occur in the longer term.

O38. Reindeer use of Yamal tundra measured with pellet-group counts: understanding reindeer effects on willow growth and recruitment in a landslide- rich area

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Rapid climate change in recent decades is a reality in Arctic regions. Trees and shrubs are expanding and the tundra is becoming greener. Reindeer have been proposed as potentially being able to suppress this greening through grazing. Quantifying reindeer use of different vegetation types in relation to landscape topography can help us understand reindeer impact on the growth of woody taxa (e.g. *Salix* spp.) and their recruitment in naturally denuded landslide areas (i.e. active layer detachment slides). This is important in order to project future patterns of greening, albedo, snow capture, and the overall resilience of tundra rangelands under further predicted climate change. Here we show preliminary results of reindeer habitat use in a tundra region of West Siberia, Russia estimated from pellet-group counts. In July 2013 and 2014, we counted pellets within 322 15m^2 plots, over a 30km^2 landslide-rich area on Yamal Peninsula. In 2013, the plots were established and we removed old pellets out of the plots. *Salix* leaves and young twigs comprise an important source of forage for migratory reindeer. Our preliminary results show high use by the reindeer of dwarf shrub (ridge-top) tundra: exposed ridges provide insect relief during summer when wind is sufficient, and willows on ridge-tops tend to be low erect or prostrate forms with strong evidence of grazing and trampling. In contrast, more concave areas (e.g. old landslides) with tall *Salix* were used less by reindeer, which were observed browsing in tall willow thickets only during cool weather (e.g. <6°C) with high winds.

O39 S. Mapping berry productivity and animal activity in Nunavut: one step toward understanding the place of berries in the Arctic biocultural system

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Berry shrubs are circumpolar species that possess high nutritional value benefitting both animals and northerners. They are known to produce a large quantity of fruit each year but how environmental and climatic factors influence their productivity is poorly understood. Numerous animal species as well as contemporary Inuit rely on berries as a local source of nutrients and vitamins. During the summer of 2014 and 2015, 30 study sites were visited in the vicinity of the communities of Kugluktuk and Arviat, Nunavut. We measured environmental variables (soil moisture, slope, orientation, soil type), plant height, species cover, animal activity (following ITEX herbivory protocol), and berry productivity in a 20 m*20 m plot at each site. We than evaluated the impact of the microenvironment as well as plant community structure and composition on animal and berry abundance. Spatial distributions of berry productivity and animal activity were map to evaluate areas that may be visited for berries. Assessing ecological processes controlling berry availability and productivity while documenting its biocultural value will help inform decisions on land use and traditional activities in the Arctic. In the context of rapid environmental and cultural change, a better understanding of the place of berries in the Arctic food web will provide tools to anticipate and mitigate changing conditions.

O40. Selective herbivory offsets carbon losses in the sub-arcic tundra

Anne Tolvanen, Henni Ylänne, Sari Stark

Selective herbivory of palatable plant species provides a competitive advantage over unpalatable plant species with slow growth rates and slowly decomposable litter. We proposed that selective herbivory may counteract the increased shrub abundance that is otherwise found in tundra ecosystems, in turn interacting with the responses of ecosystem carbon (C) stocks and CO_2 balance to climatic warming. We tested this hypothesis in a 19-year field experiment with factorial treatments of warming and simulated herbivory on the dominant deciduous dwarf shrub *Vaccinium myrtillus* in Kilpisjärvi, Finland. Warming increased the vegetation abundance with the strongest effect on deciduous dwarf shrubs. Gross ecosystem production (GEP), ecosystem respiration (ER) and C stocks were increased by warming. Simulated herbivory increased the abundance of evergreen dwarf shrubs, most importantly *Empetrum nigrum* ssp. *hermaphroditum*. There was no effect on GEP and ER or the total ecosystem C stocks by the herbivory treatment, indicating that the vegetation shift counteracted the herbivore-induced C loss from the system. A larger proportion of the total ecosystem C stock was found aboveground relative to belowground, in plots treated with simulated herbivory. We conclude that by providing a competitive advantage to unpalatable plant species with slow growth rates and long life spans, selective herbivory may promote aboveground C stocks in a warming tundra ecosystem and, through this mechanism, counteract C losses that result from plant biomass consumption.

Reference:
Ylänne, H., Stark, S. & Tolvanen, A. 2015. Vegetation shift from deciduous to evergreen dwarf shrubs in response to selective herbivory offsets carbon losses: evidence from 19 years of warming and simulated herbivory in the sub-arctic tundra. Global Change Biology *in press*.

O41. The sensitivity of carbon in Arctic permafrost soils to climate change
- A work in progress

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Arctic permafrost soils contain huge amounts of stored carbon (C), which upon thaw releases ancient organic matter that has been stored in the frozen soil for centuries. However, the critical role that the Arctic C stocks may come to play in the future of our climate system has not been adequately investigated. Particularly, there is a gap in our current knowledge as to which extent permafrost-protected C is available for microbial metabolism once the soils thaw. During 2012 samples were obtained from permafrost soils at two Arctic locations; Adventdalen (Svalbard) and Zackenberg (Greenland). At both locations sites were chosen to represent Meadow and Heath communities. Soil-pits were established and the A, B and C soil horizons were collected, together with the upper 20 cm permafrost, with three replicates for each community. Homogenized soil sample where further divided into three sub-samples. Two of the sub-samples have been incubated at +5°C with either Anaerobic or Aerobic conditions, with the third subsample sample working as a "control" incubated at -5°C. A preliminary result after 120 days incubation indicates that CO_2 emissions from drained soils (A, B and Permafrost horizons) are generally higher from Zackenberg meadow sites then the heath communities. No difference can so far be found between the Adventdalen communities. Generally the organic rich A horizon generates higher fluxes then the C (mineral soil) and Permafrost soils. First CH_4 production was detected after 56 days incubation (Zackenberg meadow A horizon) indicating that oxygen levels have dropped below the threshold for anaerobic decomposition.

POSTERS:

P1. Circumpolar Biodiversity Monitoring Program (CBMP) - Freshwater

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The Arctic Freshwater Biodiversity Monitoring Plan is the second of four pan-Arctic biodiversity monitoring plans developed by the Conservation of Arctic Flora and Fauna's Circumpolar Biodiversity Monitoring Program to detect and understand the causes of long-term change in the composition, structure and function of Arctic freshwater ecosystems. This "umbrella plan" identifies existing capacity to facilitate improved cost effective monitoring through enhanced integration and coordination. This will allow for earlier detection of disturbances and provide for faster information transfer, leading to more effective and efficient policy and management response. Objectives are to:

- Develop the critical questions to be addressed for the assessment of Arctic freshwater biodiversity;
- Identify an essential set of Focal Ecosystem Components (FECs) and indicators for freshwater ecosystems that are suited for monitoring and assessment on a circumpolar level;
- Identify abiotic parameters that are relevant to freshwater biodiversity and need ongoing monitoring;
- Articulate detailed impact hypotheses that describe the potential effects of stressors on FEC indicators;
- Determine a core set of standardized protocols and optimal sampling strategies for monitoring Arctic freshwaters that draws on existing protocols and activities;
- Create a strategy for the organization and assessment of existing research and information (scientific, community-based, and Traditional Ecological Knowledge (TEK)) to evaluate current status and trends;
- Develop a process for undertaking periodic assessments of Arctic freshwaters including details of reporting elements and schedules; and
- Identify the financial support and institutional arrangements required to undertake such a program.

P2. Permafrost thaw – decadal responses to climate change. Call for collaborations

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Permafrost soils contain approximately 1672 Pentagram carbon (C), twice the amount of the current atmosphere, and constitute 50% of the world's belowground C pool. Along with the current change in climate these high latitudinal soils experience increased temperatures, with permafrost degradation as a result. This releases ancient organic matter where the following microbial degradation can release the previously stored C and nitrogen (N) to the atmosphere as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), further influencing the climate systems. Thus, a changed climate leads to sever alterations of the C and N balance in Arctic and high altitude ecosystems. This project (starting 2016) aims for understanding the future that lies ahead, following thaw and the establishment of new non-permafrost ecosystems, and how the predicted climate variability will influence these soils on a long-term timescale. By using a natural occurring permafrost degradation gradient in the northern part of Sweden, this project investigates: the change in C and N dynamics following thaw, the decomposability of ancient carbon (through radiocarbon dating), the chemical/physical protection of ancient C, and the microbial response following degradation and during the transit to new ecosystem types. Furthermore, by using laboratory incubation of soils from the gradient, the project will provide insights of how the C and N cycles at different stages of permafrost degradation will respond to the changing climate, giving a decadal perspective on permafrost thaw.

This project is currently under planning and collaborations and side projects are encouraged.

P3. Microbial Tundra – linking vegetation changes induced by warming to microbial communities across the arctic tundra

Sara Hallin[1], Jaanis Juhanson[1], Germán Bonilla Rosso[1], Juha Alatalo[2], Björn Lindahl[1], Ulf Molau[3], Karina Clemmensen[1] and the ITEX-network

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Large-scale studies of soil microbial communities across the arctic tundra biome, similar to analyses regarding vegetation, are lacking, which hampers general conclusions concerning effects of warming and vegetation shifts on soil nitrogen (N) cycling and carbon (C) balance. Cycling of N will largely regulate the extent of the net C balance and subsequent positive climate feedbacks. However, how alterations in N cycling and the communities involved are related to ongoing and expected pan-arctic vegetation changes is not easily predicted. We are specifically interested in linking directional changes in aboveground plant communities with the belowground structure of fungal, bacterial and archaeal communities. One hypothesis is that directional changes in vegetation towards shrubs will result in a more closed N-cycle, with N cycled mainly in organic forms as a consequence of increased mycorrhizal fungal activities. Therefore, the effect of vegetation on the major inorganic N-cycling pathways in terms of genetic potential is also assessed. The preliminary results show that the bacterial and archaeal communities are more different across sites than between warming and control plots within sites. Ongoing work is focused on detailed changes in certain vegetation types and how that relates to microbial community shifts.

P4 S. N fixing activity in moss associated cyanobacteria in response to grazing and experimental warming in Tundra ecosystems

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Nitrogen (N) fixing moss associated cyanobacterial communities (MAC) are considered important contributors to the N budget in northern regions. Environmental change, including warming, is expected to affect bryophyte productivity and biomass, which may in turn cause change in N fixation patterns. In this study, we assessed the response of MAC to experimental warming in sub-arctic alpine ecosystems at two ITEX sites in Iceland (*i*) a grazed (sheep) mesic dwarf birch heathland (450 m elevation) largely covered by mosses, and (*ii*) an ungrazed *Racomitrium* moss heath on postglacial lava (120 m elevation). N fixation activity was assessed by the acetylene reduction assay (ARA). Estimation of cyanobacterial relative abundance and diversity was carried out with microscopy (phase-contrast, fluorescence and confocal scanning) and with amplification and sequencing of *nifH*/*nifD* and *rpoC* genes. Preliminary results suggested that both grazing and simulated climate warming negatively affected N fixation rates, also that the significant decrease of N fixing activity may largely depend on MAC identity and community composition. Our findings may have substantial impact on the understanding of the N cycle response to global environmental change in the Tundra.

P5 S. Impact of climate changes on plant biomass in tundra in Middle Europe (Czech Republic)

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Plant biomass production and its allocation alterations underline the sensitivity of alpine plants to global changes. Plant communities of medium-height mountains, like High Sudetes, are predicted to be markedly affected by global changes. The response of alpine-heathland biomass to altered environmental factors (higher temperature, moisture, nitrogen) was evaluated at the Giant Mts., Králický Sněžník Mts. and Hrubý Jeseník Mts (the Czech Republic) in the Middle Europe. Based on ITEX methodology, 60 plots (0,5 × 0,5 m) were established in alpine-heathlands. Permanent sampling plots with distinct treatment were set as a split-plot design. Influence of nitrogen, temperature and moisture were evaluated and plant biomass were compared after the 4-year-long exposure. Comparisons were performed for the whole biomass, aboveground and underground parts, plant functional types, and species. Alpine-heathland biomass as a whole does not differ among particular mountains and plots under investigation. Biomass changes of plant functional types and particular species distribution were recorded as a consequence of potential environmental (climate) shifts. The group of evergreen shrubs positively respond to raised temperature, on the other hand graminoids correlate positively with nitrogen. The responses of alpine heathlands to climate are prolonged and depended on species composition and only selected species will became dominant at the expenses of other functional types. .The alterations appeared to be subtle and long-term but with important consequences for conservation management.

P6 S. Warming increases arctic tundra emission of biogenic volatile organic compounds despite no vegetation changes

Magnus Kramshoej

It has been suggested that emission of biogenic volatile organic compounds (BVOCs) commence a negative feedback to climate warming in remote northern areas (Paasonen et al. 2013). Climate changes in the Arctic are projected to be more severe than averaged over the globe (IPCC 2013), and studies suggest that the magnitude of BVOC emissions in this area is particularly sensitive to these changes (Rinnan et al. 2014). Here we present *in situ* BVOC emission data from dry arctic tundra exposed to six years of experimental warming (W) or reduced sunlight (RS) simulating increased cloud cover. By taking plant biomass into account and separately assessing the emission response of the whole ecosystem, plant shoots and soil, we have identified that W directly affects emissions rather than plant biomass, leading to 3.6 times higher emission rates for the ecosystem as a whole and 1.9 times higher emission rates for plants, while having no effect on soil emissions. In RS the emission from ecosystems was 31% of the control, from plants 35-39% and from soil 22%. These results suggest that the effects of W and RS are direct, rather than a result of altered plant biomass, and moreover that warming only impacts plants rather than soil emissions. The strong emission responses presented in this study emphasize the need to reevaluate the significance of arctic regions in future emission models.

P7. A search for the uncommon: exploring fungal communities in marginal habitats of the High Arctic

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Fungi are largely understudied in the Arctic, while being essential for ecosystem functioning, both as decomposers of organic material and as partners in various symbiotic relations with plants, algae and cyanobacteria. In order to evaluate consequences of climate change on Arctic fungi, we need more base-line information; we need to know who is who, who is where and why. In this study, we present a diversity snapshot of root-associated fungi within the High-Arctic archipelago Svalbard, using *Bistorta vivipara* roots as the study system. To cover the width of diversity, we analysed 41 root-systems sampled from eight contrasting habitats; including widely distributed habitats where *B. vivipara* is common, like *Dryas* heath, and rare, more localized habitats, such as areas influenced by natural oil seeps and run-offs from hot-springs. These localized habitats are thought to harbor unique species that contribute to the overall diversity in Svalbard. In order to characterize this diversity, we used a pyrosequencing approach targeting the nuclear internal transcribed region (ITS2). We found 1092 unique fungal OTUs at 98% similarity, while 638 are known ectomycorrhizae (ECM) (on average 305 and 193 otus per sample, respectively). Common dominant OTUs throughout the habitats matched *Cortinarius* sp., *Geospora* sp., *Hebeloma ammophilum, H. leucosarx,* and unclassified fungi. A similar study, analysing 160 root-systems spanning the same geographical area but without targeting habitat diversity, found a considerably lower number of fungal OTUs (751 OTUs), indicating that these marginal habitats are important contributors to the overall diversity, and vital component to study and preserve.

KEY-WORDS: FUNGI, ECTOMYCORRHIZAE, MARGINAL HABITATS, BIODIVERSITY, SVALBARD

WORKSHOP TALKS:

Maintaining legacy in ITEX by planning for the loss of long-term sites: Alexandra Fiord

Greg Henry

ITEX is now into its 25th year, given the initial meeting in December 1990 as the starting point. I happened to established the first ITEX site at Alexandra Fiord in the Canadian High Arctic in 1992, and have managed to maintain the site since then. A very large data base of basic ITEX measurements and other related studies has been accumulated over the two decades, with the most recent addition of the common garden studies showing evidence of rapid adaptation to the warming experiments. It has been a remarkable experience and the results have contributed to the understanding of high Arctic tundra response to climate variability and change. However, it is now getting too difficult and expensive to maintain the site with the level of support received. Within the next 3-4 years, the annual research at Alexandra Fiord related to ITEX will come to an end. Planning for this must begin now, to ensure the legacy of the studies at the site is preserved and the various plots and studies are properly documented and made available for potential visits by future researchers. I will present a plan to put the ITEX research at Alexandra Fiord into torpor in a manner that will allow future researchers to easily find and re-measure plots and other sites. I will also examine the logistics of closing down the oldest warming experiment in Canada. This presents an opportunity to discuss the future of ITEX as the demography of the site population changes.