Oral presentation

Interactive effects of temperature and water level on tundra carbon flux components

Paulo C. Olivas[1] and Steve F. Oberbauer[1]

[1]*Florida International University*

Arctic regions store important amounts of soil carbon in an unstable state because of saturated soils and low temperatures. Temperature and soil water may also strongly influence the productivity of tundra ecosystems. As a result, changes in water availability and temperature could have significant effects on the carbon balance. However, as the climate changes, the direction and the magnitude of changes in the carbon balance in response to these potentially interacting physical factors are uncertain. To evaluate the effects of water regime, we have initiated a large hydrological manipulation at Barrow, Alaska where we have maintained flooded, drained, and intermediate water levels in a drained thaw lake basin. To test the interactive effects of temperature and water level, we passively increased the temperature of the surface using open top chambers (OTCs) in each of the three water-level treatments. To quantify the effects of these treatments on the ecosystem carbon balance, we measured net ecosystem exchange (NEE) and its components, ecosystem respiration (ER) and gross primary production (GPP) using static chamber methods. Growing seasons differed strongly between 2007 and 2008, the being former hotter, brighter and drier. Interannual differences in water availability revealed an important reduction in ER for both OTC and non-temperature treated plots as a consequence of increased water table in 2008. The effect of increased water table on GPP was not as strong as the effect on ER. However, in areas where most the leaf area was submerged, GPP was strongly reduced. As a result, net ecosystem exchange (NEE) was greater (stronger sink activity) in 2008 than in 2007 for the non-temperature treated plots. The OTCs enhanced the effects of lower water availability on the flux components. During the dry year (2007) both the ER and GPP were positively affected with the stronger effect on GPP. As result the NEE was higher in the OTCs. In 2008, the combination of higher water table and lower light (fewer clear days in 2008 than in 2007) resulted in lower GPP. However, these conditions also had an important effect on carbon balance in the form of strongly reduced ER in 2008. We conclude that increased water table lowers ER strongly by reducing soil oxygen availability and OTCs positively affect ER and GPP especially in areas with little standing water. However, during very dry periods (such as those present in 2007) OTCs might increase transpiration and decrease the water table reducing water availability and negatively affecting GPP especially of the moss layer.

Winter fluxes of carbon dioxide – a comparison of current methodology

Björkman M.P.[1], Morgner E.[2,4], Björk R.G.[1,3], Cooper E.J.[4], Elberling B.[2,5] and Klemendtsson L.[1]

[1]University of Gothenburg, [2]The University Centre in Svalbard, [3]Örebro University, [4]University of Tromsø, [5]University of Copenhagen

During winter as much as 47 % of the land mass of the northern hemisphere may experience the insulating effect of a snow-cover, during which vast areas have a longer snow-covered period than growing season. The snow cover allows soil microbial activities to continue during winter with a production of CO_2 as a result. Estimations of winter fluxes are difficult since snow is a highly complex media, with large uncertainties as a result. Using a newly developed trace gas diffusion technique this project aims to improve winter flux estimations and to minimise the uncertainties given by the snow-cover itself. Current methodology for winter CO_2 emissions will be presented and evaluated together with a discussion on measurement standardization.

More Arctic Snow

Elisabeth J. Cooper[1], Elke Morgner[1,2], Philip Semenchuck[1],
Julia Wdowiak[3] and Bo Elberling[2,4]

*[1]Tromsø University, [2]UNIS: University Centre in Svalbard,
[3]Lakehead University, [4]Copenhagen University*

Climate models predict that there will be an increase in the precipitation in Arctic areas, especially during winter. If this results in more snowfall in the Arctic, it may have important consequences for both the vegetation and the tundra carbon balance. Increased snow depth is likely to lead to a later snow melt and delayed start of spring growth, thus shortening the growing season considerably. It will most likely affect the plant phenology (and thereby also forage available for herbivores) in the short term, leading to changes in vegetation composition in the long term. During the winter months, a deep snow layer acts as a greater insulator than the shallow snow layers, leading to a warmer surface soil temperature, and thus a greater production of CO_2 through respiration and decomposition. Large areas of tundra could therefore be at risk of shifting their carbon balance from carbon stores to production, thus acting as a feedback to the greenhouse effect. It is therefore of great and immediate importance to study the winter carbon output in a field experiment to get accurate data for climate modellers.

Twelve snow fences were established in Adventdalen, Svalbard (78°N, 16°E) in autumn 2006 to experimentally manipulate the natural snow accumulation. These are 1.5 m high and 5 m long, with three replicates in each of four different study areas. The study areas differ in plant composition and soil moisture conditions; two are on arctic heath (dominated by *Cassiope tetragona*), two are on arctic meadow (dominated by *Luzula arcuata ssp. confusa)*. Vegetation composition studies were made in mid-season (July), plant phenology measurements were carried out throughout the growing season from snow melt to senescence (June-Sept) and tundra carbon balance was measured throughout the whole year (Jan-Nov). The results to date are presented here.

Icelandic soils in response to increasing temperatures in Iceland

Rannveig Guicharnaud

Agricultural University of Iceland, Keldnaholt, IS-112 Reykjavík, Iceland

The Arctic contains about 11% of global soil organic matter (SOM) while those areas referred to as "high-latitude ecosystems" may contain as much as 60% of all SOM. High latitude regions are experiencing the most significant impacts of climate changes and this could result in the catastrophic release of SOM in the near future. An increasing number of studies have demonstrated that microbial activity persists at ecologically significant levels during cold seasons when air temperatures goes near or below the freezing accounting for 20-70% of the annual C and N turnover. Understanding and predicting the response of soil carbon and nitrogen to changes in global temperatures is therefore critical.

Iceland is a sub-arctic region with soils of volcanic origin giving those unique properties, the most important being, in terms of climate change, unusually high accumulation of carbon and nitrogen. This high sequestering ability has been explained by protection of organic C by amorphous clay minerals commonly found in volcanic soils. More importantly Icelandic soils have been reported to sequester unusually high amounts of carbon and nitrogen and have a strikingly large soil microbial biomass compared to other soils of both higher and lower latitudes. Icelandic soils have furthermore been reported to be N limited, a common feature of arctic soil ecosystem. Moreover Icelandic soils have been reported to be biologically active (N mineralization, enzymatic activities and CO_2 release) both in thawed and frozen (-10°C) conditions. To place these results in context, climatic data for the years 2001 – 2006 revealed that gross soil respiration rates in Iceland have increased at sub-zero temperatures from a value of between 9.0 and 41.6 µg CO_2-C g^{1}_{OC} in 2001 to between 9.9 – 43.4 µg CO_2-C g^{1}_{OC} in 2006. These results demonstrate that gradual changes in temperature at higher latitudes will have considerable impacts in relation to soil carbon and nitrogen dynamics.

Long-term warming effects on greenhouse gas emissions from high Arctic tundra

Greg Henry[1], Steve Siciliano[2], Eric Lamb[2] and Ian Snape[3]

[1]Dept of Geography, University of British Columbia, Vancouver, Canada, [2]Dept of Soil Science, University of Saskatchewan, Saskatoon, Canada, [3]Dept of Environment and Water Resources, Antarctic Division, Australian Government, Kingston, Tasmania, Australia

A growing number of studies have shown that warming increases CO2 fluxes in tundra systems. In a static chamber study of the effects of warming on NEE at four ITEX sites Oberbauer et al. (2007) found that ecosystem respiration (ER) was more responsive to warming than photosynthesis. Dry tundra was most responsive with large increases in ER and effects were ecosystem dependent. Fewer studies incorporate fluxes of other greenhouse gases (GHGs), such as methane (CH4) or nitrous oxide (N2O), hence we know very little about the effects of warming on these important GHGs. In 2008, we use a newly developed fast Fourier transform infrared (FTIR) gas measurement system and automatic soil respiration chambers to simultaneously assess the fluxes of CO2, CH4 and N2O from long-term warming experiments in seven plant communities at Alexandra Fiord (79° N), Ellesmere Island, Canada. The experiments were established between 1992 and 1995 in sites that ranged from wet sedge tundra to dry polar semi-desert communities. Warming was combined with snow addition and removal at a *Cassiope* heath and with three levels of fertilization at a *Vaccinium* dominated site. Collars (ca. 15 cm diameter x 15 cm deep) were inserted into control and experimental plots and automatic chambers (n = 4 per treatment) were established over the collars and attached to the FTIR system. Measurements were conducted for 6-12 hours at each site in mid July. The fluxes of all three gases were standardized to CO2 equivalents in terms of GHG effect. The results showed that warming increased GHG emissions in wet and dry tundra, but decreased fluxes in mesic sites. The largest increases were in polar semi-desert sites, where GHG emissions increased by 20%. Nutrient additions decreased the emission of CO2 in warmed plots but increased the flux of N2O. These results indicate that: a) changes in these tundra systems will result in increased emissions of GHGs; b) polar deserts are much more important contributors of GHGs than previously thought, and warming will greatly increase the emission of GHGs from these systems; and c) increased nutrient availability will have a differential effect on GHG emissions in a warming climate.

Vegetation responses in a warming and enclosure experiment in an alpine, subarctic oceanic environment.

Anna Maria Fosaa

Faroese Museum of Natural History

The Faroe Islands ITEX site was established in 2001. Ten Open Top Chambers (OTC) were placed inside an enclosure in order to study the combined effect of warming and sheep grazing. The study site is on the mountain of Sornfelli (62°04'N, 6°57'W) at 600 m a.s.l. on Streymoy in the central part of the Faroe Islands. The temperatures are measured 1 cm below the soil surface and above the soil surface with Tiny Tag data loggers. Vegetation data were sampled in 0.25 cm^2 plots in the OTCs and control (grazed and un-grazed) plots in 2001, 2005 and 2008. Phenological studies were conducted during the growing season. Leaf areas of the two species *Salix herbacea* and *Polygonum vivipara* were measured in 2005 and 2008. Preliminary results from these studies will be presented.

Elevated CO2 and warming at treeline

Christian Rixen, Melissa Martin, Sonja Wipf, Konstantin Gavazov and Frank Hagedorn

WSL Swiss Federal Research Institute SLF, Unit Ecosystem Boundaries, Alpine Ecosystems, Flüelastrasse 11, 7260 Davos Dorf, Switzerland

Within the next decades, a two-fold increase in CO2 concentrations and a rise in temperatures by 1.4 to 5.8°C can be expected. There are many attempts to manipulate temperature conditions in situ; however, a combination of an experimental increase in CO2 and temperature has not been carried out before in the Alps.

This FACE (free air CO2 enrichment) experiment at treeline in Davos was started in 2001 and a soil warming treatment was added in 2007. We look at plant growth and fitness of tree and herbaceous plant species as well as biogeochemical cycling.

Results so far have shown enhanced growth of larch due to elevated CO2 but not of mountain pine. Several dwarf shrub species were more susceptible to frost under elevated CO2 and warming. *Vaccinium myrtillus* showed higher susceptibility to frost under elevated CO2 (Fig. 1). Carbon loss by soil respiration was more enhanced by the treatments than carbon sequestration by plant growth.

The results indicate that not all tree species at treeline respond with enhanced growth to elevated CO2. This year and coming years will show if the CO2-effect levels off and if soil warming enhances plant (and dwarf shrub) growth. Elevated CO2 and warming may increase the vulnerability of plants to frost events. Therefore, extreme events may counteract positive growth effects of climate change. The carbon pool analyses showed that the treated ecosystems are becoming an initial CO2-source. Therefore, enhanced carbon sequestration may not be expected in a warmer climate at treeline.

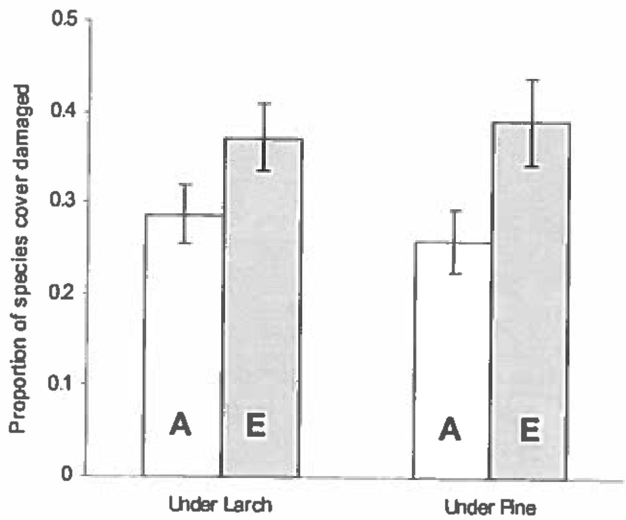

Fig. 1. Percent frost damage in Vaccinium myrtillus in response to elevated CO2 (E = elevated, A = ambient) under larch and under pine. Shown are mean values ± 1SE.

The effect of shrubs on treeline dynamics and responses to simulated environmental changes in the Central Pyrenees and in the Subarctic Scandes

Oriol Grau[1], Josep Maria Ninot[1] and Terry Callaghan[2]

[1]*Department of Plant Biology, University of Barcelona, Catalonia, Spain.*
[2]*Abisko Scientific Research Station, Lapland, Sweden*

Treeline dynamics has been widely studied in the recent years, but little attention has been put on the effect of shrubs at the forest-alpine grassland ecotones. There are positive and negative interactions between shrubs and tree seedlings which may change across altitudinal and latitudinal gradients due to changes in abiotic and biotic stress. We hypothesise that such interactions may change under varying enviromental conditions and that they may affect seedling recruitment across the treeline.

Our research is based on transplantation experiments of tree seedlings, involving simulations of changes in temperature (+/- open top chambers), nutrient availability (+/- NPK fertiliser) and shrub cover (+/- shrub removal), both above and below the treeline at two distinct latitudes. In 2006, this full factorial experiment was established at the Central Pyrenees with *Pinus uncinata* seedlings and *Rhododendron ferrugineum* low shrubs. At Abisko (Northern Sweden) a similar experiment was set with *Betula pubescens* subsp. *tortuosa* seedlings and *Vaccinium myrtillus* mats.

Since then, several variables have been measured at the beginning and ending of the growing seasons: leaf and stem measures, survival, abiotic leaf damage and herbivory. Preliminary results indicate that abiotic damage had stronger effects on seedlings without nurse facilitation from shrubs and on seedlings growing above the treeline. All the factors studied in the experiments also seem to have a significant effect on some biometric variables.

Monitoring Ammassalik Vegetation Change (MAVC)-Preliminary Results

Fred J.A. Daniëls[1] and Johannes G. de Molenaar[2]

[1]Institute of Plant Ecology, Münster, Germany, [2]Alterra, Wageningen, Netherlands

The knowledge of the low-arctic vegetation of the Ammassalik district, southeast Greenland, is mainly known from phytosociological studies recorded 1968 and 1969 by de Molenaar (1974, 1976) and Daniëls (1975, 1982). These monographs present a detailed account of the flora, plant community types and landscapes at a time when there was little human impact or global warming effect. The population of the small town of Ammassalik has grown from nearly 800 to more than 1800 residents; and now over 5000 tourists visit the district annually. Climatic changes during the last 40 years included a mean annual temperature increase from minus 2, 5°C to minus 0, 3°C, and a distinctly longer period of summer warmth. Comparisons between the periods 1963-1967 and 2002-2006 show longer and warmer summer periods and distinctly less cold and shorter winters with much less snow.

Thus in 2007 we revisited key coastal tundra plant community types near the town of Amassalik. The same team reanalysed according to the same methods nine key vegetation types (if possible the same plots or stands, if not the same types) by at least 10 relevés, and did some remapping of the vegetation. Moreover we repeated a detailed transect study from 1981. We just wanted to find out if there were vegetation changes on the plant community type level and if so to produce a plausible explanation.
A few first preliminary results are presented here.

By comparing similarities (based on the characteristic species composition and abundances of the species) of the plant community types, we might conclude, that in general vegetation composition and structure of all investigated community types appear rather stable after 40 years. The same applies for the spatial distribution of the vegetation stands. Plant community types on dry, southern-exposed sandy slopes (Festuco-Salicetum glaucae, Cladonio-Viscarietum alpinae and Caricetum bigelowii) and the zonal dwarf shrub tundra of the Empetrum hermaphroditum-Vaccinium microphyllum community type as well, show the same structure and characteristic species combination as 40 years ago. However mire vegetation (Caricetum rariflorae) and several types of snowbed vegetation (Polygono-Salicetum herbaceae, Alchemilletum alpinae, Alchemilletum glomerulantis and Hylocomio-Salicetum herbaceae) show distinct changes, probably due to drier sites conditions nowadays due to reduction of the length of the snow cover periods and longer and warmer summers.

Human impact on the vegetation is confined to the immediate surroundings of the town. More detailed multivariate comparisons between the datasets from the end of the sixties and 2007 will be carried out, which also include plant functional types and thermophily index of the species.

Internet: http://www.polarjahr.de/MAVC.268+M52087573ab0.0.html

Literature

Daniëls-FJA 1975: Vegetation of the Angmagssalik District, Southeast Greenland. III. Meddr. Grönl. 198 (3).

Daniëls-FJA 1982: Vegetation of the Angmagssalik District, Southeast Greenland. IV. Meddr. Grönl. Biosci. 10.

De Molenaar-JG 1974: Vegetation of the Angmagssalik District, Southeast Greenland. I. Meddr. Grönl. 198 (1).

De Molenaar-JG 1976: Vegetation of the Angmagssalik District, Southeast Greenland. II. Meddr. Grönl. 198 (2).

Climate data derived from DMI Technical Reports, Copenhagen, 2006 and 2007.

Diversity-stability relationships of an alpine plant community under simulated environmental change

Kari Klanderud and Ørjan Totland

Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway

We examined the relationship between plant community diversity (species richness, evenness) and stability in an alpine *Dryas octopetala* heath exposed to four years of warming (open top chambers) and nutrient addition at Finse, southern Norway. Furthermore, we examined if different functional types responded differently to the interaction between environmental change and initial community diversity. We used the temporal change in species composition, calculated as the sum of change in sample scores in detrended correspondence analyses, as a measure of variability (opposite of stability). Under ambient conditions, high initial species richness was associated with less stability of the total species composition. Under experimental warming, initial high species richness and evenness were associated with a more stable subsequent vascular species composition. Vascular stability decreased, however, with higher species richness under nutrient addition. When warming and nutrient addition were combined, high initial evenness was associated with more stable bryophyte composition, whereas high species richness was associated with reduced lichen stability. Thus, the degree and direction of the diversity-stability relationship depended on the type of environmental perturbation, the responding functional type, and on the diversity parameter used. The large variation in diversity-stability relationships is likely an outcome of complex species interactions and environmental factors influencing community diversity.

Plant responses to experimental and natural warming in Barrow and Atqasuk Alaska

Robert Slider and Robert Hollister

Grand Valley State University Arctic Ecology Program

Over the past decade the average summer temperatures in Barrow and Atqasuk, Alaska have seen a general increase. Studies at these locations have shown that experimental warming has resulted in changes in the growth and reproductive effort of tundra plants. This study seeks to compare the effects of experimental warming with changes observed in control plots over the past decade.

Plant Community Changes in Northern Alaska in Response to Warming

Jeremy May and Robert Hollister

Grand Valley State University Arctic Ecology Program

This project examines the response of plant communities in Alaska to more than a decade of experimental warming. Community change was measured using a point frame method. The response to warming included increases in the presence of bryophytes, graminoids, and deciduous shrubs. Carex aquatilis increased in prevalence by 9%, an increase that is dramatic because it is already a dominant species on the landscape. Lichens tended to show a decrease under warmed conditions. This project provides evidence that plant communities are changing in response to warming in arctic Alaska.

Effects of sudden cold temperature on *Sphagnum girgensohnii* grown under different light and temperature regimes

Steven F. Oberbauer and Sarah J. Colby

Department of Biological Sciences, Florida International University, Miami FL 33199, USA

During the short, snow-free growing seasons in the Arctic, sudden "cold snaps" or freeze thaw events (FTE) frequently occur when temperatures fall subzero for 24 to 72 h. Vascular plants exposed to FTE are often irreversibly damaged, but despite their importance, the responses of nonvascular plants to FTE have been little studied. Using controlled environment chambers, we grew plants of *Sphagnum girgensonhii,* under high and low light and temperature conditions to investigate whether pre-freeze conditions influence damage and recovery of this important moss species. Plants grown at low light and high temperature showed the greatest growth. Upon freezing they also showed irreversible physiological damage and the greatest reduction in growth. Furthermore, some growing conditions resulted in increased production of new branches that were lost during freezing. The findings of this study suggest that the responses of *Sphagnum* species to climate variation may be important for the structure of arctic plant communities.

Long-term warming and novel climate change experiments on the Tibetan Plateau

Julia A. Klein

Department of Forest, Rangeland & Watershed Stewardship, Colorado State University

In 1997, I established the Tibetan Plateau ITEX warming experiment at the Haibei research station on the northeastern region of the Tibetan Plateau (37°37'N, 101°12'E, 3200 m). I will summarize the major findings from this project, and emphasize recent results on ecosystem services. I will also discuss new research directions at the site, including warming effects on invertebrate leaf herbivory and comparisons with an IR heating experiment. I will then introduce a new study which involves OTC warming at the Nam Co Monitoring and Research Station for Multisphere Interactions (30°46'N, 90°.31'E, 4730 m). This experiment simulates two predicted climate changes -- warming and increased snow -- and two dominant types of grazing -- yak and pika grazing. The Haibei station site is characteristic of the more mesic, lower elevation, eastern region of the Tibetan Plateau, while the Nam Co station site is characteristic of the more arid, higher elevation, western region of the Tibetan Plateau. These two experiments will enhance understanding of how different regions of the Tibetan Plateau may respond to future climate changes given different pastoral management practices.

Impacts of climate change on plant-herbivore interactions in the High Arctic

Doiron Madeleine[1], Esther Lévesque [2] and Gilles Gauthier

[1]Département de biologie and Centre d'étude Nordique, Université Laval, Québec, QC, G1K 7P4.
[2]Département de chimie-biologie and Centre d'étude Nordique, Université du Québec à Trois-Rivières, QC, G5L 3A1.

Climatic models predict a global warming of 3 to 5°C over the next 60 years, and these changes will be most pronounced in Polar regions. Migratory bird species breeding in the Arctic are expected to be among the species most affected by climate change. This study examines the impact of climate change on the interactions between a herbivorous bird species, the Greater Snow Goose (*Chen caerulescens atlantica*), and its food plants on Bylot Island, Nunavut. In many herbivores such as geese, the growth and subsequent survival of young is dependent upon a good synchrony between hatching of young and seasonal change in plant nutritive quality. If plants respond more quickly than geese to global warming, this may lead to a mismatch between the availability of high quality food (expected to occur earlier with warming) and hatching date of goslings. The objective of this project is thus to test experimentally the hypothesis that global warming will have a negative impact on the synchrony between goose reproductive phenology and plant growth in the High Arctic. We are manipulating environmental parameters most likely to be affected by global changes (surface temperature and date of snow melt) using small plexiglass open-top chambers (OTC) that can increase the surface temperature by approximately 2°C, and by adding or removing snow in spring. The experiment was set up in 2006 in two dominant plant communities used by snow geese (wetlands and mesic prairies) in a randomized block design with 6 blocks, each containing 6 different treatments. Each treatment is a combination of two manipulations, either adding (+) or removing (-) snow in spring with a shovel (leading to an advance or a delay of about 7 or 5 days, respectively, in snow-melt), or presence or absence of a pair of OTC over a 2m x 2m plot. Our 6 treatments (control, +snow, -snow, OTC, +snow/OTC, -snow/OTC) allowed us to create conditions ranging from warmer early seasons (plots with OTC and snow removal) to later snow melt seasons (plots with snow addition and without OTC). In 2007 and 2008, we examined seasonal change in nutritive quality of two plant species in each habitat: *Arctagrostis latifolia* and *Luzula arctica* in mesic prairies and *Eriophorum scheuchzeri* and *Dupontia fisheri* in wetlands. From shortly after snow melt in mid-June until the end of July, we collected plant biomass every 10 days in all treatments; samples were dried and weighed, and will be analysed for nitrogen content. These manipulations will be repeated in 2008. Preliminary results of the experiment will be presented. Other ITEX projects run by Esther Lévesque's lab will also be discussed.

Recent vegetation changes in pastures in Iceland under a warming climate

Borgthór Magnússon

Icelandic Insitute of Natural History, Hlemmur 3, 105 Reykjavik, Iceland

In 1997 – 1998 one hundred permanent vegetation plots were set up in lowland and highland pastures in southern and northern Iceland. The aim of the study was to follow long-term changes in pasture condition and vegetation composition. The plots were visited for the second time in 2005. Over the period pasture condition had improved considerably. A reduction in extend of bare ground had occurred with a decrease in cryptogam cover and an increase in cover of vascular plants. Ordination of the data indicated an overall vegetation change from heaths towards grassland. These changes are attributed to a reduction in livestock grazing and a warming climate during the last decade.

Effects of climate change and land use on tundra ecosystems in Iceland

Ingibjörg S. Jónsdóttir[1], Borgthór Magnússon[2], Járngerdur Grétarsdóttir[1], Rannveig Guicharnaud[1], Bjarni Gudleifsson[1], Jón Gudmundsson[1] and Hlynur Óskarsson[1]

[1]*Agricultural University of Iceland, Keldnaholt, IS-112 Reykjavík, Iceland*
[2]*Icelandic Institute of Natural History, Hlemmur 3, IS-105 Reykjavík, Iceland*

Climate change and land use are two drivers of change in ecosystem structure and function that operate at different time scales. The impact of land use is usually much greater on a relatively short time scale compared to climate change and it may direct ecosystems responses to climate change. It is therefore essential to understand the combined effect of these drivers on ecosystem function and structure and to understand ecosystem resistance and resilience to change. In Iceland climate has warmed significantly during the last few decades and at the same time the high grazing pressure on the highland commons during summer by sheep has been relaxed in many places. The aim of this project is to study the impact of climate change and sheep grazing on tundra ecosystems in the Icelandic highlands and to explore the relationship between biodiversity, ecosystem function and stability. To assess stability we re-analyse vegetation in 12-29 year old permanent plots in different habitats, including two ITEX sites. For biodiversity we assess plants, soil and surface invertebrates and vertebrates. Ecosystem function is assessed by measuring ecosystem respiration, NDVI, soil microbial mass and nutrient availability. In this talk some preliminary results will be presented.

Cross-site comparison of indicators of ecosystem processes in response to ITEX warming.

Steven F. Oberbauer[1], Tiffany Troxler[1] and Jeff Welker[2]

[1]Department of Biological Sciences, Florida International University, Miami FL 33199, USA.
[2]University of Alaska Anchorage, Anchorage AK, 99508, USA,

As part of our IPY-ITEX cross-site comparison efforts we are comparing indices of ecosystem function in controls and experimentally warmed treatments of as many ITEX sites as possible. Indices we are comparing include peak season ^{14}C of respired CO_2, leaf ^{18}O, ^{15}N, and ^{13}C ratios, leaf nutrients, leaf lignins and tannins, soil solution nutrients, and NDVI as well as end of season leaf litter nutrients. Analyses of these samples are proceeding with some intriguing preliminary results. We still have capacity to process samples and would gladly analyze any additional samples from ITEX sites that are not among those represented.

Changes in tundra vegetation in response to current climate warming: analysis of ITEX control plot data

Sarah C. Elmendorf and Greg H.R. Henry

Geography Department, University of British Columbia

A major goal of ITEX is to predict response to future climate change, however climate warming in the arctic is already well underway. Control plot data from long-term experiments, such as ITEX, represent a unique resource for exploring how tundra vegetation may be responding to these changes. We present preliminary results from analysis of long-term vegetation trends in a select set of arctic and alpine sites. Results suggest that total above-ground growth is increasing, largely as a result of increases in graminoids and shrubs. These findings largely support predictions based on warming experiments and suggest climate-induced vegetation change may already be occurring.

Posters presentations

Effect of reduced below-ground C sequestration on greenhouse gas fluxes within dry tundra ecosystems along an altitudinal gradient

Robert G. Björk[1,2], Philip A. Wookey[3], Gustav Laggren[4], Anja Ödman[5] and Leif Klemedtsson[2,3]

[1]School of Science and Technology, Örebro University, SE-701 82 Örebro, Sweden. [2]Tellus - The Centre of Earth Systems Science, University of Gothenburg, P.O. Box 460, SE-405 30 Gothenburg, Sweden. [3]School of Biological and Environmental Sciences, University of Stirling, Stirling FK9 4LA, Scotland, U.K. [4]Department of Plant and Environmental Sciences, University of Gothenburg, P.O. Box 461, SE-405 30 Gothenburg, Sweden. [5]Department of Ecology, Lund University, Ecology Building, SE-223 62 Lund, Sweden

It has been suggested that global climate change will have a great impact on arctic and alpine areas, affecting the carbon and nitrogen dynamics in these ecosystems. Temperature is widely thought to be the main limiting factor for plants and microorganisms in these tundra ecosystems, and warming the soil in high latitude tundra has been shown to change trace gas (CO_2, CH_4, and N_2O) exchange rates and increase N availability. However, little attention has been paid, to date, to variations in trace gas fluxes with altitude, although altitude is a key determinant of temperature and should therefore be strongly correlated with these fluxes if temperature is a major variable affecting these processes. The objectives of this study were, therefore, to measure growing season variation in carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) fluxes from heath plant communities along an altitudinal gradient ranging from mid alpine (~950 m a.s.l) to high alpine (~1,365 m a.s.l) zones within an alpine tundra landscape in the subarctic region of Sweden. Furthermore, by reducing the C supply to the root system and mycorrhizal fungi (achieved by clipping the above-ground plant parts) we wanted to decrease the rhizosphere priming effect and thereby change the C sequestration pattern within the ecosystem to be able to separate heterotrophic and autotrophic respiration.

The study was conducted on the slopes of Mt. Latnjatjårro (1,447 m a.s.l.; 68°21'N, 18°31'E), near Latnjajaure Field Station, 16 km west of Abisko in Northern Sweden. Flux measurements of CO_2 were analysed using a portable infra red gas analyser (IRGA) based on the SBA-4 OEM CO_2 Analyzer (PP System). Fluxes of CH_4 and N_2O were sampled using a closed chamber system, where chambers were placed on collars, which were gently pressed into the ground. Air from the chamber was circulated into a headspace bottle and analysed by gas chromatograph. A two-step incubation technique was also used to determine Nitrification Enzyme Activity (NEA) for analysing nitrification in acid soils with low activities, and for Denitrification Enzyme Activity (DEA) an anaerobic incubation technique, based on acetylene inhibition of the N_2O-reductase, was used.

Our results show a decrease in average growing season CO_2 efflux with altitude, but not consistently, and although soil temperature in general decreased with altitude there was only a loose association between soil temperature and average growing season CO_2 efflux. Furthermore, the clipping of the above-ground plant parts reduced the CO_2 efflux at all altitudes, except at 1,225 m a.s.l., and in August the reduction in CO_2 efflux was largest at 950 m a.s.l. (231 mg CO_2 m^{-2} h^{-1}) and decreased with altitude (to 33 mg CO_2 m^{-2} h^{-1} at 1,365 m a.s.l.). However, the proportion of the reduced CO_2 efflux, corresponding to autotrophic respiration, was relatively constant with altitude (28-43% of total respiration), except at 1,365 m a.s.l. where the autotrophic respiration only contributed 12%. The fluxes of CH_4 and N_2O were very low, and resolution was constrained by the large number of samples with apparent fluxes below the limit of detection for the gas chromatograph, thus no particular pattern could be identified. However, to try to improve the resolution along the altitudinal gradient, the NEA and DEA were used, and give a potential measure of the nitrification and denitrification rates, which goes back to the actual populations of nitrifiers and denitrifiers in the soil. The results show that there were a substantial increases with altitude in the activities of nitrifying and denitrifying microbes; this is contrary to expectations and the average growing season CO_2 efflux if the decline in mean annual temperature with altitude is the main driver for nitrification and denitrification. Thus, our results are indicative of the complex interaction that may occur along altitudinal gradients. But, clearly, there is a need for further studies to assess the effects of altitude and temperature on carbon and nitrogen dynamics in high alpine and arctic ecosystems across wide altitudinal ranges.

Different aged nunataks in the Vatnajökull ice sheet, SE-Iceland, give unique opportunity for monitoring primary succession

Starri Heiðmarsson [1] and Bjarni D. Sigurdsson [2]

[1]*Icelandic Institute of Natural History (IINH), Borgir Norðurslod, IS-600 Akureyri, Iceland*
[2]*Agricultural University of Iceland, Keldnaholt, IS-112, Reykjavik, Iceland*

In Iceland glaciers reached a temporary maximum ca. in the year 1890. Since then Icelandic glaciers have been retreating at an accelerating rate and this has caused more and more nunataks to emerge from the Vatnajökull ice sheet in southeastern Iceland. Esjufjöll mountains, reaching about 1300 m a.s.l. have been exposed at least since soon after the end of last Ice-Age. Further down in the outlet-glacier, Breiðamerkurjökull, three younger nunataks have emerged in the past century. Kárasker emerged before 1940, Bræðrasker around 1960 and the youngest one, Maríusker, emerged in 2000. This offers unique opportunities to study how different lifeforms colonize surfaces that emerge from retreating glaciers and how the initial communities change with time (primary succession).

Monitoring of vascular plants started already in 1965, when the botanist Eythor Einarsson established permanent plots in the nunataks Kárasker and Bræðrasker. Those plots have been remeasured and in 2005-2006 similar plots were established in Esjufjöll and Maríusker, so the study now contains a chronosequence of different aged nunataks.

During 2008 we installed an automatic climatic station in Kárasker, which is the most centrally located nunatak. There, irradiance, air temperature, frequency of wind directions and speeds and the duration of soil thawing is monitored at a 1 h resolution. Also, a PhD student at Lund University, María Ingimarsdóttir, added studies on how soil fauna and other insects colonize the nunataks and how their colonisation is linked to vegetation succession and physical factors.

Some initial findings from the vegetation part of the project will be presented. Vascular plants are the group best studied, with more than 100 species recorded. Also, more than 100 species of bryophytes s. lat. have been found growing on the nunataks, but lichens seem to be slower colonizers on the youngest nunataks than the bryophytes. In Esjufjöll some rare lichen species, such as *Umbilicaria virginis* and *Dermatocarpon bachmannii*, have been found.

Grand Valley State University REU Projects at Barrow & Atqasuk

R.D. Hollister, J.L. May, R.T. Slider, A.M. Snyder and M.L. Lothschutz,

Grand Valley State University Arctic Ecology Program

The AON Program of NSF/OPP has supported Research Experiences for Undergraduates (REU) at Barrow and Atqasuk in association with the ongoing GVSU ITEX research. These opportunities have allowed students to take a leadership role in the research and allowed the project to examine interesting auxiliary topics. During field season 2007 and 2008 four students participated. The individual student poster panels presented here are extracted from presentations presented elsewhere.

High Arctic heath responses to ambient and simulated climate change

James Hudson and Greg Henry

UBC, Department of Geography

The Canadian High Arctic has recently warmed and this trend is expected to continue. Increased temperatures are expected to alter the composition and functioning of plant communities. For the past 16 years, we have measured plant responses to both ambient and simulated climate change in a heath community at Alexandra Fiord, Nunavut. Over this period, mean annual temperature, thawing degree days, and growing season length have increased, which have affected maximum thaw depth but not soil moisture content. Ambient warming has shifted the composition of the heath community. Evergreen shrub and moss cover have increased while lichen cover has decreased. Also, canopy height and species richness have both increased. Notably, this community has become significantly more productive over time.

The simulated climate change experiment, however, has not produced the same responses as ambient warming. In the experiment, we first manipulated temperature and growing season length in 1992 and 1995, respectively. The strongest treatment effects were observed early on in the experiment in response to passive warming, but have become dampened over time. The growing season length manipulation has not influenced plant composition or abundance.

Surprisingly, it appears as though ambient warming has strongly affected community structure and functioning in this High Arctic heath while the experimental treatments have not. As this is a conservative, slow-growing community, this suggests that many tundra plant communities may have already shifted as a result of recent climate change.

Experimental warming and fertilization (1996-2007) shifts plant functional community composition and fine scale spatial stability in subarctic alpine meadows

Saewan Koh and David S. Hik

Department of Biology, University of Alberta, Edmonton, Canada

We measured the effects of 11 years of experimental warming and fertilizing on plant functional community composition and spatial stability in a sub-arctic alpine meadow in southwest Yukon, Canada.

In 1996, 1998, 2002 and 2007 we scored 5 cm x 5 cm subquadrats within 25 cm x 25 cm quadrats inside 4m x 4m open top chambers (N = 8) and in nearby adjacent control plots. Half of the OTCs and control plots were fertilized with nitrogen (at 20 g m^2) to complete a cross factorial design (with warming). Spatial stability over time was calculated with Moran's I. Moran's I measures spatial autocorrelation and determines departures from randomness of objects in 2-d space.

Significant increases in the cover of graminoids over time in fertilizer treatments (2% to 18%-26%)were associated with increases in Moran's I (more clustering). In these treatments forbs decreased in cover and became more dispersed. We suggest that graminoids were better able to uptake the additional nitrogen, became better competitors for light and thus shaded out more prostrate functional types such as forbs. Dispersion of deciduous shrubs with increases in cover (7% to 18%) suggest they were able to exploit patches between larger graminoid tussocks.

Within control and warming treatments deciduous shrubs showed the greatest increases in cover relative to other groups (from 4%-6% to 12%-13%) but remained spatially stable. Graminoids did not change in cover but became more dispersed over time.

Ordinations (non-metric multidimensional scaling) show that fertilizer treatments were associated with greater variations in plant functional community structure compared to control and warming treatments.

We discuss implications of shifts in plant functional groups over time in alpine tundra undergoing climate change.

Responses of two deciduous shrub species to long-term snow addition and increased air temperatures in the Arctic tundra of Northern Alaska

Robert Pattison[1], Jeff Welker[1,2], Bjartmar Sveinbjörnsson[1,2], Patrick Sullivan[1,2] and Jeremy Chignell[1,2]

[1]*Environment and Natural Resource Institute*
[2]*Department of Biological Sciences, University of Alaska, Anchorage, AK.*

Arctic vegetative ecosystems are undergoing substantial changes highlighted by increased shrub dominance. We examined leaf level and morphological responses of two shrub species to short and long term snow and temperature manipulations designed to simulate components of climatic change potentially contributing shrub expansion. We used two species that have shown differential responses to experimental warming and to fertilization in these nutrient limited systems. *Betula nana* has shown a positive response while *Salix pulchra* has shown a negative response. In this study we examine the long term (12 year) effects of deeper snow and warming. In addition we recently established a new set of snow manipulations to attempt to differentiate the multifaceted effects of snow- including warming soil temperatures in winter, added snow melt water in the spring, plus a shortening of the growing season.

There were no differences in photosynthetic rates between *B. nana* and *S. pulchra* for any of the combinations of long-term snow addition and/or increased air temperatures or at the shrub patch. These results are consistent with long term fertilization and warming studies1. Both species showed positive photosynthetic responses to both warming and snow addition. However the increases were not additive. *Betula* tended to have lower $\partial^{13}C$ and $\partial^{15}N$ than *Salix* across treatments however there were few differences between treatments.

Short-term snow accumulation increased photosynthetic rates for *B. nana*. The combined effects of snow addition and early season snow removal (to account for decreased growing season length) appeared to have an additive effect for both species. Adding early season water had a differential affect on the two species with *S. pulchra* showing a slightly positive effect relative to snow addition and early season removal. However, for *B. nana* watering appeared to negate the positive effects of snow accumulation. This result along with consistent differences between the two species in $\partial^{13}C$ suggests potential differences in the water relations of these two species that requires further investigation. Similarly species differences in $\partial^{15}N$ suggest that these species may use different sources of nitrogen. As different precipitation events can have distinct $\partial^{15}N$ signatures, further investigation may determine if differences between species in $\partial^{15}N$ and $\partial^{13}C$ are related.

Betula nana stems were taller in the long-term snow addition treatment than in ambient snow. Plots in the long-term snow addition treatment also had higher LAI's than those in the ambient treatment. These results are consistent with other studies and suggest that long-term snow addition alters plant biomass allocation strategies with potential implications for competitive interactions. Further research is needed to understand both of these processes and their interactions with snow accumulation.