11th International Tundra Experiment workshop
ITEX2002

Programme

Abstracts

Participants

Hotell Finse 1222 4th– 7th October 2002

Department of Biology and Nature Conservation
The Agricultural University of Norway

PROGRAMME

Time	Name	Title/Activity
Friday 4 October		
-20.30	Most participants	Arrival
20.30-21.00	Finse 1222 Hotel	Presentation about Finse
21.00-	Most participants	**Dinner and social activities**
Saturday 5 October		
08.00-09.00	All participants	**Breakfast**
09.00-09.10	Ørjan Totland	Welcome to ITEX 2002
09.10-09.30	Phil Wookey	ITEX at Finse and beyond: the objectives of the meeting
09.30-10.00	Marilyn Walker	The ITEX community synthesis
10.00-10.15	Phil Wookey	Introduction to the IASC-ITEX joint biodiversity initiative
10.15-10.35	Rien Aerts	Effects of experimentally imposed climatic scenarios on flowering phenology and flower production of sub-arctic bog species at Abisko, Sweden
10.35-11.00	All participants	**Break/coffee**
11.00-11.20	Ingibjörg S. Jónsdóttir	Climate Change Impact on High Arctic Ecosystems: ITEX related research on Svalbard
11.20-11.40	Sofie Sjögersten Turner	Soil C and nutrient dynamics at the forest-tundra ecotone, Scandes mountains
11.40-12.00	Greg Henry	Effects of long-term warming experiments at Alexandra Fiord: from plant to ecosystem level
12.00-12.20	Esther Lévesque	Site report Canada: Baker Lake, Bylot Island, Tanquary Fiord
12.20-13.30		**Lunch**
13.30-13.50	Masaki Uchida	Factors influencing net ecosystem production in a high Arctic polar semi-desert, Ny-Ålesund, Svalbard
13.50-14.10	Jeff Welker	Recent findings from the NATEX network and the Biocomplexity of Arctic systems as a component of future ITEX themes
14.10-14.30	Robert D. Hollister	Response of tundra vegetation to variation in temperature: Implications for forecasting future vegetation change
14.30-14.50	Ulf Molau	ITEX proliferating at Latnjajaure, Sweden
14.50-15.05		**Coffee**
15.05-15.25	Kari Klanderud	Impacts of climate change on plant species diversity of *Dryas* heath communities in alpine south Norway
15.25-15.45	Henrik Wahren	Vegetation responses in Alaskan arctic tundra after six years of a summer warming and winter snow manipulation experiment
15.45-16.05	Anna Maria Fosaa	A presentation of the newly established ITEX field site in the Faroe Islands
16.05-16.25	Line Nybakken	Is UV-B protection in arctic-alpine plants influenced by other environmental factors than UV-B itself?
16.25-16.40		**Coffee**
16.40– 17.00	Sylvi M. Sandvik	Effects of Open Top Chambers in a wet late-melting

		snowbed
17.00–17.20	Brigitta Erschbamer	A modified ITEX in the Central Alps, Austria
17.20-17.40	Borgthór Magnússon	ITEX sites in Iceland 2000 – 2002: progress report
17.40-18.00		**Break**
18.00-18.20	Wookey et al.	Objectives and organisations of working groups
18.20-18.40	All participants	Plenary discussion of proposals for Working Groups
18.40-19.00	All participants	Construction of Working Groups for Sunday 6th Oct.
19.00-	All Participants	**Dinner/social activities**

Sunday 6 October

08.00-09.00	All participants	**Breakfast**
09.00-11.00	All participants	Working group session I (including break)
11.00-11.30	All participants	Plenary reporting of working groups
11.30-12.00	All participants	Plenary discussion of working groups, and proposal for WG session II
12.00-13.00	All participants	**Lunch**
13.00-15.00	All participants	Physical exercises in the mountains
15.00-15.30	Those who need	Relaxation and **coffee**
15.30-17.00	All participants	Working group session II
17.00-17.30	All participants	Plenary reporting of working groups
17.30-18.00	All participants	Plenary discussion of working groups and proposals for WG session III (`Task forces`)
18.00-18.15	All participants	Organisation into task forces
18.15-19.15	All participants	Poster session
19.30-	All participants	**Dinner and social interactions**

Monday 6 October

08.00-09.00	All participants	**Breakfast**
09.00-10.30	All participants	Task force
10.30-10.50	All participants	**Coffee**
10.50-11.30	All participants	Task force
11.30-12.00	All participants	Plenary reporting of task force progress
12.00-12.30	All participants	Summing-up and allocation of continuing tasks. Formal close of meeting
12.30-13.30	Most participants	**Lunch**
13.30-15.00	Some participants	Task forces continue

POSTERS

Tracey Baldwin and Steven F. Oberbauer	Presence of Essential Oil Producing Glands on the Stems of *Ledum palustre* ssp. *decumbens* and ssp. *Groenlandicum*
David Bean and Greg H. R. Henry	The Spatial Distribution of Vegetation in a High Arctic Oasis

David Bean and Greg H. R. Henry	Climate Change Impacts on Tundra Ecosystems: the CANTTEX Network of Ecological Monitoring Sites in the Canadian Arctic
Amy Carroll	
Sarah Colby and Steven F. Oberbauer	The change in *Sphagnum* abundance under two climate change scenarios at Toolik lake
Elisabeth J. Cooper, Inger G. Alsos, Dagmar Hagen, Fiona M. Smith, Stephen Coulson, Ian Hodkinson	Reproduction by seeds in Svalbard
H.E. Epstein, M.P. Calef, M.D. Walker, F.S. Chapin III and A.M Starfield	Detecting changes in arctic tundra plant communities in response to warming over decadal time
Jörg Löffler, Oliver-D. Finch, Jürgen Naujok & Roland Pape	Ecological Process Systems and Biocoenoses in the Norwegian High Mountains. Theory and Methodology of a new Project
Oliver-D. Finch, Jörg Löffler, Jürgen Naujok, Roland Pape	Climate, Soil and Vegetation: Spatiotemporal Patterns of Arthropods in High Mountain Ecosystems of Central Norway
Steven F. Oberbauer, Craig E. Tweedie, Andrea L. Kuchy, Patrick J. Webber, Robert D. Hollister, Greg Starr, and Elizabeth F. Elmore	Tundra carbon fluxes in response to experimental warming along moisture and climate gradients in N Northern Alaska
Inga Parker and Steven F. Oberbauer	Relating seasonal patterns of NDVI to CO_2 flux for climate change scenarios in Arctic Alaska.
Shelly Rayback and G.H.R. Henry	Use of *Cassiope tetragona* in Retrospective Studies in the Canadian High Arctic
Steven P. Rewa, Craig E. Tweedie, Robert D. Hollister, and Patrick J. Webber	The Role of Site Moisture in the Long-term Recovery of Arctic Tundra from Vehicle Disturbance
Sandra G. Rolph, Greg H. R. Henry, and Cindy E. Prescott	Effects of ITEX warming experiments on nitrogen cycling in the Canadian High Arctic
Heather M. Rueth, Gaius R. Shaver, and James A. Laundre	Long-term Responses of Soil Temperature to Manipulations of Nutrient Availability and Air Temperature at Toolik Lake, Alaska
Sullivan, P.F., J.M. Welker and J.T. Fahnestock	Growing season patterns in *Eriophorum vaginatum* L. biomass allocation: the influence of experimental manipulation

ABSTRACTS

Effects of experimentally imposed climatic scenarios on flowering phenology and flower production of sub-arctic bog species at Abisko, Sweden

Aerts, R.[1], Cornelissen, J.H.C.[1], Dorrepaal, E.[1], van Logtestijn, R.S.P.[1], Callaghan T.V.[2]
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Climate scenarios for high latitude areas do not only predict increased summer temperatures, but also larger variation in winter snow fall and winter temperatures. So far, only little is known about the effects of variation in winter snow fall and temperature on high-latitude ecosystems. We experimentally manipulated both spring and summer temperatures and winter snow accumulation and temperatures in a blanket bog in sub-arctic Sweden and studied the effects on flowering phenology and flower production of *Rubus chamaemorus* (herbaceous) and *Andromeda polifolia* (woody evergreen).
Our winter manipulations led to consistent increases in winter snow cover. Due to the insulating effect of the snow cover, average and minimum air and soil temperatures in the high snow cover treatments were higher than in the winter ambient treatments. Spring warming resulted in marginally significant higher average and minimum soil temperatures and significantly higher maximum soil temperatures. As expected, summer warming led to higher air and soil temperatures in mid-summer (June-July), but not in late summer (August-September).
The spring warming treatments resulted already after one year in earlier flowering in summer of both *Rubus* and *Andromeda*. In *Andromeda*, this was the most pronounced in the treatment that combined increased winter snow accumulation and spring and summer warming. In addition, total flower production of *Andromeda* was also higher in the spring warming treatments. The other treatments had no effect on the reproductive characteristics of these species. Our results show that the reproductive ecology of both species is very responsive to climate change and that especially spring events have a strong impact. This supports recent suggestions that climate change experiments should focus more on winter and spring events than has been the case so far.

Climate Change Impact on High Arctic Ecosystems: ITEX related research on Svalbard

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The High Arctic has been relatively poorly represented within the network of ITEX sites and one of the few High Arctic sites, the Svalbard site, dropped out some years ago. This summer, however, Svalbard has been brought back to the ITEX map as an active ITEX site through a new project. Based on the notion that changes in the wither climate have relative large effect on high arctic ecosystems, the main focus is on variable winter conditions: 'The effect of winter conditions on arctic plant populations and vegetation'. With the aid of a remote digital camera snow accumulation and redistribution throughout the winter, and snowmelt in spring, are monitored at the landscape level at two sites with contrasting climatic conditions: one relatively warm and dry and another cooler and wetter. ITEX designed OTCs will be used to study the interaction between winter conditions and summer warming. Several environmental factors are monitored along with population and community processes. The aim is a long term monitoring in combination with experimentation and to eventually bring in additional experiments (snow manipulation) and ecosystem components (biological processes in the soil).

The status of Svalbard as an active ITEX site will be further secured in January next year when an EU funded project starts up: Fragility of Arctic Goose Habitat: Impacts of Land use Conservation and Elevated Temperatures, FRAGILE. As elsewhere in the Arctic, breeding goose populations on Svalbard have been increasing in recent years as a consequence of changes in land use and bird protection measures. The aim of the project is to provide mechanistic and predictive understanding of the impact of these factors on arctic ecosystems in the context of climate change and vulnerability of arctic tundra ecosystems to increase in breeding goose populations. One of objectives is to identify ecosystem processes, which are most vulnerable to the combination of increasing grazing pressure and climate warming and to determine thresholds for ecosystem degradation through factorial field experimentation with variable grazing pressures and ITEX designed OTCs.

Soil C and nutrient dynamics at the forest-tundra ecotone, Scandes mountains

Sofie Sjøgersten Turner

The response of whole-ecosystem carbon storage in high latitude environments to climate warming is still uncertain. Although above-ground vegetation responses have received most of the attention so far, there is increasing interest in plant-soil interactions, and feedback processes between soils and the atmosphere. Both the vegetation and soil sub-systems can respond directly to a changing environment, but they also respond indirectly via alterations in the structure and function of other components of the ecosystem. Thus changes in the quality and/or quantity of litter entering the decomposition subsystem will influence rates of decomposition, CO_2 efflux and nutrient mineralization, which in their turn can influence subsequent plant growth. Also, direct responses of the soil subsystem to climatic changes can influence plant growth via changes in nutrient availability and/or soil organic matter (SOM) characteristics. We have therefore studied the response of soil carbon and nutrient dynamics to environment at the mountain birch forest-tundra ecotone during four field seasons in the Fennoscandian mountains. The main objectives of the study were: (i) to quantify trace gas fluxes (methane and carbon dioxide) between mesic soils and the atmosphere, and (ii) to investigate the links between the physical environment, above-ground vegetation communities, soil carbon storage, nutrient status and the chemical composition of the SOM. The field sites were located at Kongsvold, Dovrefjell (Norway); Abisko and Vassijaure (Sweden); and Joatka, Finnmark (Norway). At each site both tundra heath and mountain birch forest were studied, and we used both natural gradients (incorporating latitude, altitude, continentality, and the forest-tundra ecotone) in combination with experimental warming (ITEX OTCs) to address these issues in a medium-term project. Generally, these mesic soils showed methane uptake from the atmosphere ('methanotrophy') that is likely to increase in response to a warmer climate setting: No differences between forest or tundra soils could be detected. However, for carbon dioxide efflux (soil respiration), as well as for litter decomposition, higher activity was noted at our forest sites. Soil respiration increased with temperature during the thaw season until low soil moisture levels became limiting. Also, for litter decomposition the impact of the drier surface environment within the OTCs reduced decomposition rates. We link the higher decomposition rates within the forest environment to the more favourable physical environment there (rather than SOM quality) since tundra soils stored a large amount of labile carbon that could readily be accessed by micro-organisms when transferred to a forest environment. However, a laboratory incubation experiment and a 'buried bag' N-mineralisation experiment, indicate that the organic matter quality is higher in forest soils compared to tundra.

The major conclusions presented here are that (1) methane uptake in mesic soils in the Scandinavian mountains represents a negative feedback in a warmer climate, and (2) soil carbon storage is likely to be reduced if mountain birch forest replaces tundra heath areas.

Effects of long-term warming experiments at Alexandra Fiord: from plant to ecosystem level

Greg Henry, Dept of Geography, University of British Columbia, Vancouver, Canada

Open-top chambers have been in place since 1992 in five tundra community types along a moisture gradient at a high arctic lowland on Ellesmere Island (79°N). Standard ITEX monitoring of phenology, growth and reproductive effort has been conducted on eleven species in each year; plant community structure was assessed 4 and 9 years after establishment; soil and plant nutrient status and fluxes were measured 5 and 10 years after establishment; and net ecosystem production (NEP) was measured over the 9th and 10th year. The responses of *Dryas integrifolia* will be used to illustrate annual variations in plant level variables over the duration of the experiment. Phenological responses are highly variable from year to year, but warming does result in accelerated phenology with the earliest stages showing the strongest responses. There has been no consistent effect on later stages. *Dryas* shows some important lag effects that complicate the interpretation of phenological responses: e.g. delays in phenology are associated with long warm summers in the previous year. Also, there has not been a consistent, long-term trend in the phenological responses of *Dryas* to warming. Growth has been assessed by measuring the height of the peduncle, which is confounded by the level of fertilization. However, maximum flower heights showed no consistent treatment effect, but large annual variations. Composition and abundance of species has changed significantly in all warming plots in all community types. The shifts in dominance has been towards species that display a more flexible response to warming, and are able to maintain their internal C:N ratios, despite increased net production. Warming has increased N availability in both inorganic and organic forms, and the graminoids and forbs appear to be able to take advantage of this increase. The increase in plant cover over the decade has resulted in a slight decrease in soil surface temperature, which may decrease decomposition and mineralization, although both processes have been stimulated by warming over the decade. The effect of long-term warming on NEP was dependent on habitat, but photosynthesis was stimulated more than respiration in all but the driest site, where stimulation of respiration matched that of photosynthesis. Most of the results are consistent with the forecasts that high arctic ecosystems will generally show relatively strong positive responses to warming at all levels, and that the responses are maintained over at least 10 years.

Factors influencing net ecosystem production in a high Arctic polar semi-desert, Ny-Ålesund, Svalbard

UCHIDA M. , MO W., MURAOKA H., NAKATSUBO T., KANDA H. and KOIZUMI H.

In the high Arctic, extensive land areas show a 20th-century warming trend in air temperature of as much as 5•. Moreover, substantial warming and increases in precipitation are projected over the 21th-century by major climate models (IPCC 2001). It is considered that the matter flow rates in the high Arctic ecosystem are strongly temperature-limited and therefore especially sensitive to the warming. However, the factors influencing net ecosystem production in the high Arctic terrestrial ecosystem have not been fully clarified. As a part of the study of carbon cycle on a deglaciated area in Ny-Ålesund, Svalbard, Norway (79° N), we examined effects of biotic and abiotic factors on net ecosystem production on a glacier foreland in the high Arctic. The study site was set on an old moraine in the deglaciated area of the East Bl□gger Glacier. The site was characterized by a patterned ground composed of small high-centered polygons. A mixed community of bryophytes such as *Sanionia uncinata* and vascular plants (mainly *Salix polaris*) covered the marginal part of the polygons, whereas the central part consisted of almost bare ground and/or black crusts of cyanobacteria and lichens. Net ecosystem production in the community was measured *in situ* using a portable infrared gas analyzer (LI-COR, LI-6400) with a clear acrylic chamber. The measurement of ecosystem CO_2 flux was carried out from 15 July to 11 August 2001. During the gas exchange measurement, temperatures of *S. polaris* leaf, green moss layer and soil layer (-3 cm from moss surface) were monitored. Photosynthetic photon flux density (PPFD) was also measured. After the measurement, moss samples were collected to determine their water content. Under ambient meteorological conditions, the net ecosystem production varied widely from –44 to 171 (average 43) $mgCO_2$-C m^{-2} h^{-1}. Early in the growing season, the ecosystem tended to be net sources of CO_2 to the atmosphere because of low photosynthetic activities and small leaf biomass of *S. polaris*. After rainy days, however, the ecosystem became a large sink of CO_2 because of a higher photosynthetic activity of the mosses. Diurnal patterns of net ecosystem production and dark respiration were best explained by changes in PPFD and soil temperature, respectively. It was suggested that the factors controlling net ecosystem production in the growing season are leaf-age dependence of photosynthetic activity and leaf biomass of *S. polaris*, moss water content, light incidence, precipitation and temperature.

Recent findings from the NATEX network and the Biocomplexity of Arctic systems as a component of future ITEX themes.

J M Welker, P Sullivan, J Fahnestock, G Henry, & K O'dea. [1]Colorado State University and the [2]University of British Columbia.

We have conducted ITEX experiments at Toolik Lake, AK and at Alexandra Fiord over the past three years addressing tundra responses to climate warming and deeper snow cover. In this presentation, we will highlight our findings of how warmer temperatures affect tundra net ecosystem C flux; and how deeper snow increases winter CO_2 fluxes, increases N mineralization and alters the patterns of root growth as observed using minirhizotrons. In addition, we are now in the processes of establishing a similar set of experimental treatments at Thule, Greenland as part of a new NSF Biocomplexity in the Environment project. The framework of the biocomplexity project will be presented in the context of future ITEX trajectories and in the context of stimulating discussions as to how ITEX complements emerging programs.

Response of Tundra Vegetation to Variation in Temperature: Implications for forecasting future vegetation change

Robert D. Hollister, Patrick J. Webber, Steven P. Rewa, Craig E. Tweedie, Arctic Ecology Laboratory, Plant Biology Department, Michigan State University

The response of tundra vegetation to variation in temperature due to natural temperature gradients, interannual variability, and experimental warming was examined at four field sites in Northern Alaska. The sites spanned a temperature gradient from warmer Atqasuk to cooler Barrow and moisture gradients from dry heaths to wet meadows. At each site 24 plots were experimentally warmed and monitored with small open-top chambers for at least 5 years; an equal number of un-manipulated control plots were also monitored. The affect of the warming treatment on plant microenvironments varied between the four sites. There was generally a consistent relationship between accumulated thawing degree-days and plant response variables irrespective of treatment for most species for all years of observation; therefore, experimental warming was considered to be a reasonable analog of regional climate warming. The response of plant species to changes in temperature on the phenological events -leaf emergence, visible buds, flowering, and visible fruit- as well as the growth characteristics -leaf length, leaf number, and change in overall size- and the reproductive characteristics - percentage flowering, inflorescence length, and number of flowers per inflorescence- was measured and categorized into response groups. These response groups may be of value in forecasting future vegetation change in response to climate warming. Community attributes of the sites were measured after at least 5 growing seasons of experimental warming. Overall changes in the communities were subtle. The trajectories of species composition and cover change in the communities after experimental warming were different for each site. These findings suggest the response of tundra plant species to warming is complex and varies greatly by species and habitat type. Therefore it is likely that in the near future the most accurate forecasts of the future state of regional tundra vegetation will be derived from *in situ* experimental manipulations rather than physiological modeling. This study is a contribution to the ITEX (International Tundra Experiment). Funding support from the United States National Science Foundation is gratefully acknowledged.

ITEX proliferating at Latnjajaure, Sweden

Ulf Molau, Dept. of Botany, Göteborg University, Sweden

The basic ITEX manipulation was set up at the Swedish site, Latnjajaure (subarctic-alpine) in early June 1993 for a number of target species. The five first summers we ran a full ITEX protocol, but since then we have reduced the monitoring to a "light" version. In the summer of 2002, however, we returned to the full-scale ITEX protocol (including individual seed or fruit weights, etc.) since this was the tenth year of continuous manipulation at our site. The data set is not yet fully processed, but some general observations are made. Most effects, phenological as well as quantitative, seem to level out after the initial three treatment years. The long-term data from Latnjajaure will be incorporated in ACIA (Arctic Climate Impact Assessment).

From the basic ITEX level, the field work program at Latnjajaure during the past five years has proliferated in various directions. Most of the ongoing efforts are at the landscape level, grouped under a GIS-based project in landscape ecology, Tundra Landscape Dynamics (TLD). Components encompass e.g., snow-melt dynamics, plant biomass and productivity, seed rain, bird territories, grazing impacts, and soil properties. Accumulation of atmospheric nitrogen deposition in snowbeds and its impacts on plant cover and soil nitrification potential is the most recently added topic (August 2002).

Based on the ITEX experience, Latnjajaure has become a partner site in two EU projects, DART (treeline dynamics) and GLORIA (long-term monitoring of plant cover changes on alpine summits).

Warm summers have been increasingly common since the onset of monitoring at Latnja in 1990. In 2002, the months of April, May, June, and August were record-breaking. August 2002 was the warmest month on record during this thirteen-year period of climate studies, and with a mean temperature of +10.4C this was the first time a monthly mean exceeded 10 degrees C. Taken together, the 2002 summer in northern Scandinavia appears to have been the warmest since the Bronze Age, according to specialists in dendrochronology. Summer temperatures do, however, fluctuate strongly among years; the most steady signal at the Latnjajaure site is increasing spring and fall temperatures and thereby a longer growing season. Young mountain birch trees (some over 0.5 m in height) are now found up to 500 m of altitude above the present tree-line. Most of these are 20-40 years old, but exhibiting increased long-shoot growth in recent years.

Impacts of climate change on plant species diversity of *Dryas* heath communities in alpine south Norway

Kari Klanderud and Ørjan Totland, Department of Biology and Nature Conservation, The Agricultural University of Norway, P.O. Box 5014, N-1432 Ås

Climate change may affect alpine plant community diversity by altering the dominance relationship between species. *Dryas octopetala* is a dwarf-shrub providing dense mats, which may have positive or negative effects on other species. This project aims to answer: 1. How climate change may impact the population density of *Dryas octopetala*. 2. Which effects *Dryas* has on population dynamics, growth and reproduction of other species. 3. How competition from *Dryas* and dispersal limitations for other species may impact species diversity in these areas, and how the importance of these factors may change under global warming. The study area is Sandalsnuten (1550 m elevation) at Finse, Hardangervidda, southern Norway. The experiments will last from 2000 - 2004.

To study if *Dryas* density will change under global warming, we measure leaf and shoot growth and seed production under warmed (OTC) and fertilized conditions. Results after two years show that warming and the combined effect of warming and fertilizer increase number of seeds per individual. Both warming, fertilizing and the combined effect of warming and fertilizing increase seed weight. We measure *Dryas* density to be able to model changes in community compositions and diversity as a function of changed biotic and abiotic environmental conditions. In addition to the experiments, we have studied the effect of *Dryas* on species diversity in communities with different temperature at Finse and on Svalbard. At Finse, species richness is higher inside than outside *Dryas*, whereas there is no difference on Svalbard, exept for bryophytes, which have a higher richness inside than outside *Dryas*. This indicate that *Dryas* has a neutral to positive effect on other species in extreme Arctic environments (facilitation), and mainly negative effects on other species in more productive alpine communities.

Dispersal ability is in many communities the most important factor for species diversity. Therefore we study which effect *Dryas*, dispersal limitations for other species, and abiotic factors may have on species diversity, to understand how the effects of these factors may change under global warming. Seeds from 27 species are collected in a species rich part of the area and sown in vegetation with lower diversity in the same area, with and without experimental warming. The highest germination frequency two years after sowing is in plots with a high frequency of bare soil and low vegetation cover, whereas few seedlings are observed in the dense *Dryas* mats. No difference is observed inside and outside OTCs. Most of the species germinate, including those that did not occur in the area prior to the sowing.

To understand the direct effect of *Dryas* on other species, and to study if the effect of *Dryas* is modified by abiotic conditions and nutrient availability, we compared growth and reproduction of two common species in the *Dryas* community (*Carex vaginata* and *Thalictrum alpinum*), inside and outside *Dryas*, in plots where *Dryas* is removed experimentally, and under warmed and fertilized conditions.

Vegetation responses in Alaskan arctic tundra after six years of a summer warming and winter snow manipulation experiment

Henrik Wahren

We used snowfences and small (1 m^2) open-topped chambers (OTCs) to study the effects of changes in winter snow cover and summer air temperatures on arctic tundra. In 1994, two 60 m long, 2.8 m high snowfences, one in moist and the other in dry tundra, were erected at Toolik Lake, Alaska. OTCs paired with unwarmed plots, are placed along each experimental snow gradient and in control areas adjacent to the snowdrifts. After six years, the vegetation of both sites, including that in control plots, had changed significantly. The cover of shrubs, live vegetation, and litter, together with canopy height, had all increased, while lichen cover and diversity had decreased. At the moist site, bryophytes decreased in cover, while an increase in graminoids was almost entirely due to the sedge *Eriophorum vaginatum*. These community changes were consistent with other, similar studies in the arctic, and with predicted vegetation responses to climate warming, especially the increase in shrub cover. We therefore attribute vegetation changes within control plots to regional climate warming.

The snow addition treatment affected most community attributes, whereas the warming treatment had few measurable effects. These were surprising results, given the initial growth and phenological responses from our and other arctic sites. Temperature increases within OTCs (<2°C), however, were considerably smaller than inter-annual temperature fluctuations. Also, snow addition had a greater affect on microclimate by insulating vegetation from wind and temperature extremes, and modifying soil temperatures. Most increase in shrub cover and canopy height occurred at medium to deep snow depths. These vegetation changes were considered an indirect effect of greater nutrient availability resulting from higher soil temperatures and increases in rate of decomposition. At the moist site, deciduous shrubs increased in cover, while evergreen shrubs decreased; responses that were probably a funtion of the greater production to biomass ratio and more flexible growth response in deciduous shrubs. At the dry site, where deciduous shrubs were a minor component, evergreen shrubs increased in cover and canopy height. The decrease in abundance of lichens and bryophytes at the two sites was probably a response to the increase in both snow and vascular plant cover. Thus, the decrease in diversity was due to changes in relative abundance of resident species, rather than loss of species. These community changes are expected to continue and likely to affect most ecological processes, especially the rate of litter decomposition, nutrient cycling, and both soil carbon and nitrogen pools.

A presentation of the newly established ITEX field site in the Faroe Islands

Anna Maria Fosaa, Faroese Museum of Natural History, Department of Botany, Debesartrøð, FO-100 Tórshavn, Faroe Islands; Fax +298 318438; E-mail anmarfos@ngs.fo

In November 2001 an ITEX field site was established in the Faroe Islands (62°N, 7°W). The locality is in the arctic alpine zone at an altitude of 600 m a.s.l on the mountain Sornfelli. In this area the main vegetation types are *Racomitrium* vegetation and open grassland vegetation. The temperature in the area is around 7,5°C (August mean) and 0,8°C (February mean). The vegetation in the OTC and control plots have been measured within 0,25 m^2. And the frequency of all plant species were measured based on presence/absence from 1-25. During the growing season, photos have been taken at around 7-10 days interval inside the OTC and of equal amount of control plots. Temperatures have also been measured 1 cm below the soil surface and on the top of the vegetation. A presentation of the vegetation and climate in the Faroe Islands as general and some preliminary results from the field site will be given.

Is UV-B protection in arctic-alpine plants influenced by other environmental factors than UV-B itself ?

Line Nybakken, Kari Klanderud and Ørjan Totland, Department of Biology and Nature Conservation, Box 5014, Agricultural University of Norway, N-1432 Ås

With depletion of the stratospheric ozone layer over northern regions, plants at Finse, Norway, will experience enhanced UV-B irradiation. Plants may protect themselves against such damaging irradiation by screening compounds located in the epidermis. The screening capacity of a plant can be measured using a recently developed chlorophyll fluorescence assay. Research has shown that a certain part of the UV-screening compounds may be constitutive, and that such pigments also may be induced by UV-B itself (acclimation). It is proposed, however that UV-absorbing flavonoids may be induced in plants by other environmental factors than UV. We have studied the influence of enhanced temperature, fertilization (NPK) and the combination of these two factors on epidermal UV-transmittance in *Bistorta vivipara* and *Dryas octopetala* at Finse, and will present some preliminary results. Abstracts

Effects of Open Top Chambers in a wet late-melting snowbed

Sylvi M. Sandvik, Einar Heegaard, Reidar Elven, Vigdis Vandvik

For 6 years we studied the influence of experimental warming on community composition, species richness, and the abundance of individual species in a wet late-melting snow bed. Overall, the species composition of the studied snow bed community changed significantly with time in controls and in the OTCs. There was a slightly increased invasion rate in the OTCs compared to the controls' but there was no significant difference in the overall species composition or in the species richness between the controls and the OTCs. Six years is probably to short time to cause significant temperature response in invasion and extinction rate and community composition. However, the significant influence of year suggests that a succession is present, and that the effect of the succession overrides the effect of the temperature treatment. The declining p-values for the temperature effect on the community composition suggests however, that the community composition may become significantly different in the future. The number of ramets increased more in the OTCs than in the controls, suggesting that temperature had a positive effect on the vegetative growth and the formation of tillers. Hence, as there was no difference in species richness between the controls and the OTCs the increased number of ramets must be due to increased density of the individual species already existing within the community prior to the analysis. As the number of ramets in the plots increased, the amount of bare soil decreased proportional with time, in both the controls and the OTCs. We suggest that a combination of increased growth of the plants and a net invasion of species in this particular snow bed cause succession towards a denser vegetation cover.

A modified ITEX in the Central Alps, Austria

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In 1996, 10 open-top-chambers (OTCs) were established on the glacier foreland of the Rotmoosferner (Ötztal, Tyrol, Austria) to study the effects of elevated temperatures on the growth of early and late successional species. The OTCs should induce an increase in the mean ambient temperature by at least 1°C throughout the snow-free season (= minimum IPCC scenario) and they were left on the field site also during winter.
Seedlings of *Trifolium pallescens* (early successional species) and ramet groups of *Carex curvula* (late successional species) were transplanted to the OTCs and to control plots. All plants showed a considerable transplantation shock. However, the survival of *Trifolium* seedlings was significantly higher in the OTCs compared to the control plots.
In 1998, two additional OTCs were set up and vegetative propagules of *Poa alpina* f. *vivipara* were transplanted to the new OTCs and controls and to those sites where *Trifolium pallescens* died off.
Growth dynamics of the transplanted individuals were followed over five and three years, respectively. After the harvest in August 2000, *Trifolium* showed a significantly higher total phytomass in the OTCs than in the control plots. In contrast, *Poa* was negatively affected by the artificial warming.
The *Carex curvula* plants remained there for further monitoring. In 2001, a new experiment was started with *Artemisia genipi* and *Anthyllis vulneraria* ssp. *alpestris*.

ITEX sites in Iceland 2000 – 2002: progress report

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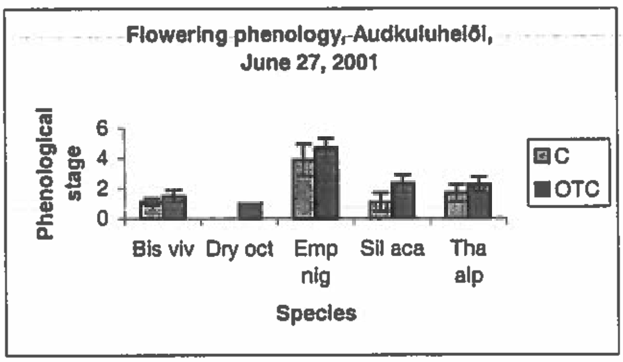
The two sites in Iceland, Thingvellir and Audkuluheidi, have been in operation since 1995 and 1996. Thingvellir is a lowland site with very species poor *Racometrium lanuginosum* heath on lava. The Audkuluheidi site is a relatively species-rich dwarf shrub heath (*Betula nana/Empetrum nigrum)* in the highlands. Initial community sampling was conducted during 1995 – 1997 and they were repeated at both sites in 2000. The data was contributed to the meta-analysis workshop of Itex community data in Boulder in 2001. Flowering phenology of selected species has been studied at both sites since 1998. Air temperature has been monitored over the growing season with data loggers.

An average temperature increase of 0,3 – 2,0 °C over the growing season has been measured within OTC chambers compared to controls, varying between sites and years.

DCA-ordination of the community data revealed that after 5 years at the Thingvellir site, definite changes in vegetation composition could neither be detected within control nor OTC plots. At the Audkuluheidi site, on the other hand, a change in vegetation composition had occurred within OTC plots following 3 – 4 years of treatment, mainly due to an increase in cover of shrubs and decline of bryophytes.



The study of flowering phenology of eight species (e.g. *Bistorta vivipara, Dryas octopetala, Empetrum nigrum, Silene acaulis, Thalictrum alpinum*) has shown hastening of flowering and seed formation within OTC plots for most species, with *Silene acaulis* having the strongest response (see figure).

The main funding agency of the study has been the National Research Council of Iceland. The project is now completing the second of a three year funding period. Future funding and continuation of the project in Iceland is uncertain.

POSTER ABSTRACTS

Presence of Essential Oil Producing Glands on the Stems of *Ledum palustre* ssp. *decumbens* and ssp. *Groenlandicum*

Tracey A. Baldwin and Steven F. Oberbauer, Florida International University

The essential oils of *Ledum palustre* ssp *decumbens* and ssp *groenlandicum* are both economically and ecologically important. Economically the essential oils are valuable as flavoring and therapeutic agents used medicinally by native peoples and homeopaths in more mainstream alternative medicine. Ecologically this species represents 50 % or more of the vegetation in arctic communities with the essential oils acting as allopathic agents in the suppression of *Picea mariana* (black spruce) seedling growth. Published reports indicate essential oil production is limited to only leaves of *L palustre* with little to no oil found in the stems of these plants and an associated analysis of the oil from the leaves either for quantitative or qualitative data. Recent collections from northern Alaska suggest this is an incorrect generalization for these two subspecies. Visual and olfactory observations and compound microscope images confirm the presence of essential oil producing hairs with glands on the stems. Further research will be conducted to verify the quantities as well as the composition of the essential oil production in the stem to ascertain variation between previously reported studies that failed to account for stem essential oil production. In addition, this new evidence serves as the initial data collection in a comprehensive study of essential oil variation along a latitudinal gradient and resource availability experiment. This study will contribute to the understanding of essential oil variation in resource allocation as well as the general knowledge in an ecologically important species under globally changing climatic conditions.

The Spatial Distribution of Vegetation in a High Arctic Oasis

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The relationships among plant community structure, diversity, phenology, and abiotic factors including snowmelt pattern, temperature, soil moisture and soil nutrients were studied at the Alexandra Fiord lowland, a high arctic oasis on the east coast of Ellesmere Island. Digital aerial photographs were used to map the pattern of snowmelt over the lowland. Twenty-eight sampling points were distributed systematically across the lowland where soils were sampled for moisture and nutrients, air temperature was recorded on data loggers, four species of vascular plants were monitored for phenology and growth, and vegetation composition and abundance was measured using point frames. Classification divided the vegetation into five plant communities with strong spatial aggregation, but the pattern of snow melt was more patchy than the landscape-scale distribution of plant communities. Using a GIS, analyses of the data from the discrete sampling points revealed a similar gradient in temperature and timing of phenological events.

Climate Change Impacts on Tundra Ecosystems: the CANTTEX Network of Ecological Monitoring Sites in the Canadian Arctic

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The Canadian Tundra Taiga Experiment was established in 1998 as part of the Ecological Monitoring and Assessment Network in the North (EMAN-North) as a network of scientists and sites across the Canadian North to monitor changes in terrestrial ecosystems. The CANTTEX network currently consists of 13 sites spread across the country and includes boreal alpine, high subarctic taiga and arctic tundra ecosystems. Monitoring of plant phenology and growth generally follows ITEX protocols, and six of the sites have warming experiments. To illustrate the results from the network, we examined the phenological responses of the most common woody and non-woody species to annual climate variations. The analysis did not show any consistent pattern among sites, which is in keeping with known regional climate differences. The major conclusion from the analyses is that there is a lack of useful, long-term data on responses of northern ecosystems in Canada to climate change, and this limits our ability to forecast important ecological changes.

THE CHANGE IN *SPHAGNUM* ABUNDANCE UNDER TWO CLIMATE CHANGE SCENARIOS AT TOOLIK LAKE, ALASKA

Sarah J Colby and Steven F Oberbauer

Climate models predict that climate warming will be the greatest at high latitudes. Along with temperature, the length of growing seasons is anticipated to increase with climate change in the Arctic. Under these climate conditions, arctic plant species have been found to have different short-term physiological responses. As a consequence, it has been suggested that the individual responses exhibited by these species will drive a shift in community composition. Accounting for a significant portion of the community in wet tussock-tundra, *Sphagnum* species assist in maintaining a shallow belowground active layer. Over a five-year period, we investigated how the abundance of *Sphagnum* species was affected by two climate change scenarios: a longer growing season and an extended growing season with belowground warming. Findings indicate a positive correlation between belowground warming and *Sphagnum* abundances in the latter years of the treatment. Because *Sphagnum* is incapable of storing any long-term physiological effect, our results point to a potential larger community structure change.

Reproduction by seeds in Svalbard

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The Svalbard archipelago in the European High Arctic is a species rich area compared to other High Arctic areas at the same latitudes. Knowledge about seed viability, composition and density of the soil seed bank, and of natural seedling occurrence in the field is very limited. This study aims to add new knowledge about the reproduction by seeds in Svalbard.

This study concerns 72 of the 161 vascular species in Svalbard's flora. The species in this study are representative of the total flora of Svalbard with respect to geographical distribution, frequency and life form, as most species are common, perennial herbs with a circumpolar distribution. Species with the ability for sexual reproduction have higher frequency in the seed bank and as seedlings in the field than for the total Svalbard flora. There is relatively high frequency of insect pollinated species among the seed bank species compared to the total flora.

Fifty species germinated from the seed bank, and 27 species were recorded as seedlings in the field. The density of seedlings and the number of species were examined at 6 dry sites from three regions in western Svalbard: moraine vegetation had 12 seedlings m-2 (3 species), pioneer vegetation 131(16), Dryas heath 91(13), mixed heath 715(25), thermophilic slope 3113(26), birdcliff 10437(10). The number of species in the seed bank is related to the number of species in the vegetation of the individual sites. All species present in the vegetation closest to the moraine have the ability to reproduce by seeds on Svalbard, and are present in the germinable seed bank of one or more sites in this study. The density of seedlings recorded in the seed bank and in the field of the same site is within the same range.

The recovery potential following disturbance is probably good for the common, hardy arctic species in Svalbard as seed bank densities and seedlings observed in field were large at least in some habitats. The rare and thermophilous species, however, have low recovery and dispersal ability under the prevailing climate. Although the species are expected to show increased sexual reproduction in a warmer climate, their fate following increased temperature depends largely on the present population sizes and gene pools in Svalbard, and their response to competition from other species.

Detecting changes in arctic tundra plant communities in response to warming over decadal time scales

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Detecting the response of vegetation to climate forcing as distinct from spatial and temporal variability may be difficult, if not impossible, over the typical duration of most field studies. We analyzed the spatial and interannual variability of plant functional type biomass from field studies in low arctic tussock tundra and compared these to climate change simulations of plant community composition using a dynamic tundra vegetation model (ArcVeg). There was substantial spatial heterogeneity of peak season live aboveground biomass in low arctic tundra at Ivotuk, Alaska (68.5 N, 155.7 W) in 1999, when samples were collected from 0.1 m^2 plots. Coefficients of variation for live aboveground biomass ranged from 41% for deciduous shrubs, 80% for graminoids and 84% for mosses to over 200% for lichens and forbs. Spatial heterogeneity in the ArcVeg dynamic vegetation model, generated as a result of grazing, soil disturbances and demographic stochasticity, compared favorably to the field data. Field studies also indicate a high degree of interannual variability with possible trends associated with warmer climates, such as increasing shrub biomass and declining moss biomass. These field data coupled with ArcVeg simulations suggest that some changes in plant community composition might be detectable within one or two decades following the onset of warming, and shrubs and mosses might be key indicators of community change. Model simulations also project increasing landscape scale spatial heterogeneity (particularly of shrubs) with increasing temperatures.

Ecological Process Systems and Biocoenoses in the Norwegian High Mountains - Theory and Methodology of a New Project –

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Landscape-ecological investigations have been carried out in the Norwegian high mountains since 1994 dealing with landscape structure and ecosystem functioning [1]. Correlations between vegetation cover and soil distribution, humus forms and water household as well as snow cover and air-, surface- and soil-temperature regimes have been described and analysed showing a very complex spatial organisation of the high mountain ecosystems [2, 3].

Simultaneous, in this way tremendous data for the examination of further aspects concerning high mountain ecology is supplied. So, as an additional compartment, at community and ecosystem levels zoological aspects were integrated into the investigations in the year 2000 [4]. Here, with respect to biodiversity and life strategies of animals, the effects of the various ecofactors are of special interest. Spatial and temporal distribution patterns of epigeic arthropods will be analysed as to their dependence on the temporal dynamics of the energy balance, soil water status, vegetation patterns etc.

The theoretical and methodological framework of the project is derived from the Landscape-Ecological Complex Analysis [5, 6] and its variations due to technical and principle methodical challenges in this high mountain landscape.

The aim of the project is to characterize the structure, functioning and dynamic of the high mountain ecosystems within small catchment areas of different altitudinal belts in the Central Norwegian continental region and the Western Norwegian oceanic region.

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Tundra carbon fluxes in response to experimental warming along moisture and climate gradients in Northern Alaska

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As part of the International Tundra Experiment, we compared ecosystem CO2 exchange from experimentally-warmed and control plots in both wet and dry tundra communities at two locations in Northern Alaska, Barrow and Atqasuk. Measurements were made during the growing seasons of both 2000 and 2001. Fluxes were assessed using static chamber techniques conducted over 24 hr sample periods sampled regularly throughout the summer. Net ecosystem exchange (NEE) from the wet tundra at both sites were largely positive (carbon uptake) during the growing season. Warming tended to increase carbon uptake on the wet sites. In contrast, NEE from the dry tundra at both Barrow and Atqasuk were largely negative (carbon losses) throughout the growing season. Warming exacerbated carbon losses on the dry sites. The effects of warming were stronger during 2000 than in 2001 at both sites and in both habitat types. Fluxes of controls were similar between the two sites but warming had a stronger impact on the dry site at Barrow than Atqasuk. Measurements of ecosystem dark respiration were used to estimate gross ecosystem uptake in 2001. These findings indicate that warming tends to increase photosynthetic uptake on all sites, but on dry sites the corresponding increase in respiration was even greater. The results of this study suggest that climate warming will enhance carbon uptake on wet sites but will increase the rate of carbon losses from dry sites.

Climate, Soil and Vegetation: Spatiotemporal Patterns of Arthropods in High Mountain Ecosystems of Central Norway

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The organization of zoocoenoses and the mobility of animals are investigated within small catchment areas in high mountain landscapes in correlation to the spatial and temporal dynamics of different environmental factors [1]. We chose one investigation region in oceanic Western Norway and one in the sub-continental part of Central Norway. In both regions two representative small representative catchments of the low-alpine and mid-alpine belt were selected as investigation areas. Here environmental variables like soil types, soil humidity and vegetation were mapped. Classification using characteristic combinations of factors reveals a spatial arrangement of ecotopes within those areas. The interdisciplinary project enables us to correlate detailed, field measured environmental factors concerning different aspects of climate (e.g. temperature, humidity, radiation) as well as patterns of soil and vegetation with the distribution patterns of arthropods. During the snow free season of the year 2001 communities of epigeic arthropods (Araneae, Carabidae, and Staphylinidae) were investigated using intensive pitfall trapping with 300 traps altogether.

Actually first results can be presented for the carabid beetles (Carabidae) and the rove beetles (Staphylinidae). Only 17 species of Carabidae (786 individuals) were recorded in the trapping season of 2001 in the 300 pitfall traps. Whereas the sub-alpine plots are richest in species number (7 and 9 species; 3 traps each), in the small catchments situated above tree line only 5-6 species occurred in the 44-85 traps per site.
At the level of single investigation sites, we search for differential species and characteristic species in high mountain habitats. For example, in the eastern low alpine catchment *Amara alpina* prefers the ridges and their surroundings, the upper parts of the slopes. Highest activity of this species was measured in the *Cladonia* and *Cetraria* dominated lichen heaths. *Patrobus assimilis* was dominant in depressions, were *Betula* and *Salix* shrubs characterize the higher vegetation and *Sphagnum* mosses cover the ground and show high humidity.
Both families show different activity patterns throughout the snow free season: Carabids are spring active. The rove beetles show an acitivity peak during summer with a clear second peak in autumn.

On broader scales, differences between the altitudinal belts of each investigation region are evaluated as well as differences among ecosystems and their faunal structure along the broad-scale oceanic-continental gradient from western to eastern Norway.
In a medium term perspective ecosystem interactions at the spot will modelled, and quantified local results are entered into a GIS for spatial analysis. The long term aim is to regionalize the results on ecological process systems and biocoenoses so that larger areas of the Central Norwegian mountains can be characterized.

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Relating seasonal patterns of NDVI to CO_2 flux for climate change scenarios in Arctic Alaska.

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Seasonal changes in ecosystem CO_2 flux result from the combined patterns of leaf phenology of the individual species components, but ascribing flux patterns to individual species or functional groups is problematic. Climate changes will differentially affect leaf phenology of component species, resulting in changing patterns of ecosystem CO_2 flux. As part of the ITEX program, we have been measuring CO_2 flux and the Normalized Difference Vegetation Index (NDVI) on season manipulation treatments to investigate the relationship between Gross Primary Productivity (GPP) and NDVI. CO_2 flux has been measured using static chambers and NDVI has been measured using an Agricultural Digital Camera (ADC), which provides a spatial representation of NDVI on the study plots. Rectified images provide the ability to perform specific area comparisons of NDVI and CO_2 flux. Significant correlations between CO_2 flux and NDVI for chamber areas have been found with data from 2001 and 2002. These correlations provide the opportunity to overlay NDVI difference coverages with point frame functional group data for the chamber flux areas using GIS. Evaluations of these overlays should indicate which functional groups are responsible for the major seasonal changes in NDVI/CO_2 flux within treatments.

Use of *Cassiope tetragona* in Retrospective Studies in the Canadian High Arctic

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Cassiope tetragona, a circumpolar evergreen dwarf shrub was used in two retrospective studies at Alexandra Fiord, Ellesmere Island, Canada. Using modified dendrochronological methods, the historical vegetative and reproductive responses of *C. tetragona* to climate variables were reconstructed. In the first study, the vegetative and reproductive response of *C. tetragona* to experimental warming in the ITEX open-topped chambers and control conditions were reconstructed for the period prior to (1986-1991) and during (1992-1998) the warming treatment. Reproductive parameters, including flower bud and flower production, responded significantly to the warming treatment, but vegetative growth did not. Examination of the correlations between vegetative and reproductive parameters and monthly climate variables proved problematic. In the second study, a proxy of summer temperature from 1899 to1996 was reconstructed for Alexandra Fiord. The proxy climate record clearly shows, 1) the warming trend in the Canadian Arctic which began in the 1920s and lasted until the early 1960s, 2) the gradual decline in summer temperature throughout the 1960s and 1970s, and 3) the recent increase in temperature beginning in the 1980s. Our reconstruction is supported by other proxy data, including ice core melt records and tree-ring reconstructions as well as instrumental data. This reconstruction contributes much needed annually resolved data to the growing proxy climate data set for the Canadian Arctic.

The Role of Site Moisture in the Long-term Recovery of Arctic Tundra from Vehicle Disturbance

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Historically, off-road vehicles have been widely used by researchers for transportation to field-research sites around Barrow, Alaska. Recently, off-road travel has increased markedly around Barrow, as the local residents have acquired a great variety of vehicles. Different types of vegetation respond differently to vehicle traffic and the effects on vegetation may remain for many years with site moisture appearing to be a major determinant of resilience. Over the course of the summer of 2001 data were collected to determine how site moisture affects the recovery rate of vehicle-disturbed tundra.

Four sites were selected in association with abandoned vehicle trails. The trails were abandoned upon completion of the studies involved with them and the dates of abandonment are reasonably well known, and range from 27 to 38 years of recovery. A total of 39 plots were established on these trails in a number of habitat/moisture regimes. Each plot is composed of a 2m x 10m grid with 80 grid cells of 0.5m x 0.5m and transects a trail. At each plot the seasonal progression of soil thaw, soil moisture and pH, micro-relief and plant community composition were measured. Plots were divided into two subplots consisting of all impacted grid cells or all control grid cells.

A comparison of impacted and control subplots was derived using principal components analysis. Impacted subplots showed less variation than the control plots. This suggests that impacted subplots are still at earlier successional stages. This hypothesis is further supported by the absence of 15 moss and lichen species from impacted subplots, which are present in the controls. Axis 1 of the ordination corresponds most closely with percent of bare soil ($r^2 = 0.371$), axis 2 with average soil pH ($r^2 = 0.111$), and axis 3 with late season thaw depth ($r^2 = 0.243$). Percent soil moisture has a lower correlation with these axes (r^2=0.244, 0.002, 0.182 respectively).

Results of a cluster analysis classify the sites into 3 distinct moisture classes, which approximate wet meadows, dry heaths, and moist tundra. However, in a few cases impacted subplots classify quite differently from the corresponding control subplots.

Other interpretations for the amount of variation among impacted plots and variation in the physical conditions of the plots will be discussed.

Effects of ITEX warming experiments on nitrogen cycling in the Canadian High Arctic

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The increased net production and CO_2 absorption by tundra ecosystems in response to warming may be constrained by the availability of nitrogen. The focus of this research was to examine the changes in soil nitrogen availability and acquisition of nutrients by plants in response to experimental warming at the long-term ITEX site at Alexandra Fiord, Ellesmere Island, Canada (79°N). Experimental plots were established in 1992 in five tundra plant communities arrayed along a moisture gradient. Open-top chambers on half the plots increased growing season temperatures by 1-3° C.

During the 2001 growing season (10 years after the warming experiments were established), the nitrogen economy was examined at each of the five community types. Ion exchange membranes (IEMs) were used to obtain a relative index of nitrogen availability in the experimental plots and among the five tundra types. Soil nitrogen mineralization, microbial nitrogen immobilization, and dissolved organic nitrogen transformation were examined using the buried bag method over the growing season. Preliminary finding indicate that increased temperatures has increased availability of both inorganic and organic forms of nitrogen, and that immobilization by soil microbes also increases in response to long-term warming. There were also important habitat differences, with some of the greatest responses found in the wet and dry community types. Some implications of these changes in soil nutrient availability are discussed in relation to plant level C:N ratios, differential stimulation of plant growth and vegetation change.

Long-term Responses of Soil Temperature to Manipulations of Nutrient Availability and Air Temperature at Toolik Lake, Alaska

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We examined the long-term responses of soil temperature in acidic tussock tundra and wet sedge tundra to manipulations in nutrient availability and air temperature at Toolik Lake, Alaska. The treatments have been ongoing since 1989. Changes in vegetation characteristics such as biomass and species composition associated with the treatments have been documented. Here we present the treatment effects on soil thermal regimes and the implications such changes could have on soil respiration. A simple relationship between soil respiration and temperature was used to determine the relative importance of changes in growing season verses over-winter soil temperature on soil process rates. Regardless of site or treatment the largest treatment effects on soil temperature were seen during peak summer and winter. The rate at which soil warmed or cooled seasonally was also similar across treatments. At the tussock site, summer soil temperatures were lower in the greenhouse + fertilized and fertilized plots compared to the control. Over-winter temperatures were 1 to 2 degrees warmer in the greenhouse and greenhouse + fertilized treatments compared to the control. Prior to the winter of 1997-98 the fertilized treatment had lower temperatures compared to the control, however afterwards fertilized temperatures were greater. Summer wet sedge soil temperatures were 1 to 2 degrees warmer in the greenhouse plot and cooler in the fertilized plot. The greenhouse treatment produced the opposite response at the two sites; at the tussock site winters were warmer and summer cooler but at the wet sedge site winters were cooler and summers warmer. Biologically significant changes in soil temperature were observed and we attribute these differences to alterations in the insolating effects of the vegetation (aboveground biomass, litter accumulation and species composition).

Growing season patterns in *Eriophorum vaginatum* L. biomass allocation: the influence of experimental manipulation

Sullivan, P.F., J.M. Welker and J.T. Fahnestock

Detailed comprehension of bigeochemical cycling under current and future climate regimes requires a thorough knowledge of root dynamics. With recent improvements in optic and electronic technology, minirhizotron camera systems have become a useful tool for measuring aspects of the belowground dynamic in some natural systems. This study used minirhizotron camera technology during 2001 and 2002 at the Toolik Lake Long Term Ecological Research site in Northern Alaska. Growing season patterns in root production rate and leaf growth rate were examined in the arctic sedge, *Eriophorum vaginatum* L. under ambient, warmed and fertilized conditions. Experimental results demonstrate a similar response to warming and fertilization. Aboveground, and belowground, plants were physiologically and phenologically plastic in their response. Warmed and fertilized plants exhibited higher leaf growth rates, greater maximum leaf lengths and earlier emergence of the season's final leaf cohort. Belowground, warmed plants produced roots at a faster rate than plants in control plots, but these high rates were confined to an early- and late-season peak. In fertilized plots, plants responded with just an early season peak in root production rate, but one with rates that exceeded those seen under ambient and warmed conditions. Similarity in warming and fertilization response characteristics may have arisen independently, or warming and fertilization may act upon the same proximal variable (i.e., plant-available nutrients). The identification of driving variables and the range of environmental conditions over which *E. vaginatum* can capitalize will further our mechanistic understanding of current growing season allocation patterns and facilitate prediction of future species assemblages and interactions.

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