Oral Presentation Abstracts

Studying the effects of climate change in the tundra biome – experimental approaches

Philip Wookey

Uppsala University, Sweden

Effects of environmental change upon ecosystems manifest themselves across a broad range of time-scales depending upon the processes of interest. Metabolic processes such as photosynthesis and respiration can respond to changing conditions within seconds to minutes, while allocation (e.g. of mineral nutrients, or photosynthate) to different structures/tissues within organisms might respond over hours to weeks: community and genetic change may operate on decadal to millennial time-scales. Clearly biological and biogeochemical adjustments to change do not always lend themselves to straightforward 'real-time' observation or experimentation. Cutting across these temporal dynamics is spatial heterogeneity and landscape complexity, which can further modify responses to change, both in terms of magnitude, and possibly even direction. Understanding the dynamics of ecosystem response to a changing environment, with multiple facets of change occurring simultaneously, thus clearly presents a major challenge to the research community. The bad news is that none of the approaches available to us is perfect: they all have their strengths and weaknesses. Experimental approaches can be criticised due (i) to the short time-scales usually involved, (ii) inappropriate spatial scales (e.g. research plots not adequately covering environmental variability), or (iii) to experimental artefacts (e.g. inadvertent modification of environmental parameters other than those of interest, or inappropriate environmental regimes). Equally persuasive criticisms can be levelled at monitoring activities, and other approaches applied to understanding environmental change impacts (e.g. the use of environmental gradients (so-called space-for-time substitution), and palaeo-environmental studies). So when can we use experimental approaches effectively, and what can we learn from them? This presentation will take a critical look at environmental manipulation experiments in arctic and alpine settings, and, by drawing contrasts with other possible approaches, attempt to highlight their successes and failings.

ITEX (the International Tundra Experiment) is central to this presentation, and can continue to play a pivotal role in global change research for a second decade, and well beyond. The challenge for ITEX is to retain the basic tenets of the successful original programme (a set of standardised measurements across a broad range of sites, based upon a clear manual) whilst embracing new opportunities offered by major advances in, for example, molecular genetics, geographical information systems (GIS), remote sensing, statistical meta-analysis, and even soil organic matter analysis (e.g. ^{13}C NMR). ITEX will also need to integrate closely with other international initiatives (e.g. CEON, the Circum-arctic Environmental Observatories Network; IASC, the International Arctic Science Committee; IPA, the International Permafrost Association; and SEARCH, A Study of Environmental Arctic Change) in order to scale-up to global processes and to make the connection between terrestrial ecosystems and other components of the Arctic system (e.g. freshwater, coastal and marine), including human society.

Plant response to temperature change in northern Alaska

Robert D. Hollister *, Patrick J. Webber

Department of Plant Biology, Michigan State University, U.S.A.
*** corresponding author**

This long-term, multi-species study re-establishes that temperature affects the functioning of plants in their natural environment; however, it demonstrates that the influence of temperature should be considered in the context of other fluctuating factors within a given location. This study examined natural temperature gradients, interannual variability, and experimental warming at sites near Barrow (71°18' N 156°40' W) and Atqasuk (70°29' N 157°25' W) in northern Alaska. At each of the four sites 24 plots were experimentally warmed for 5-7 years with small open-top chambers and plant growth and phenology were monitored; an equal number of un-manipulated control plots were monitored. The response of 7 traits from 32 plant species occurring in at least one site is reported when there were at least 3 years of recordings. Plants responded to temperature in 130 of 267 observations (49%) of a trait of a species in a site. The most common response to warming was earlier phenological development and increased growth and reproductive effort. However, the total response of a species (all traits examined) was individualistic and varied among sites. In 37 of 267 observations (14%) the plant trait was correlated with thawing degree-day totals from snowmelt (TDD_{sm}) and temperature was considered the dominant factor. In 73 of 267 observations (35%) the plant trait responded to warming but the interannual variation in the trait was not correlated with TDD_{sm} and temperature was considered subordinate to other factors. The abundance of temperature responses that were considered subordinate to other factors suggest that prediction of plant response to temperature that does not account for natural fluctuations may over estimate the importance of temperature and lead to unrealistic projections of the rate of vegetation change due to climate warming.
This project was supported with grants from the Arctic System Science Program, National Science Foundation.

Relating NDVI to ecosystem CO2 exchange patterns in response to season length and climate manipulations in Arctic Alaska

Steven F. Oberbauer, Inga C. Parker, Thomas E. Philippi, Tracey A. Baldwin, and Sarah J. Colby

Florida International University, Miami, Florida, USA

Climate change in the Arctic will differentially affect leaf phenology and species composition of tundra, resulting in changing patterns and magnitudes of ecosystem CO2 flux. To assess how well such changes might be evaluated using remote sensing, ecosystem CO2 fluxes from within permanent chamber bases and normalized difference vegetation index (NDVI) images of the base areas were compared throughout the 2002 growing season on experimental plots manipulating growing season length and soil temperature. Carbon dioxide fluxes were measured using static chamber techniques and NDVI images were taken with an agricultural digital camera (ADC). The seasonal patterns of NDVI and gross primary productivity (GPP) showed an increase to a peak in early August, followed by an abrupt decline. Net ecosystem exchange (NEE) showed an uptake of CO2 by the ecosystem in the early season leveling out to a slight loss of CO2 at peak season for control and extended season plots. NDVI was significantly correlated to GPP and ecosystem respiration (R2 = 0.51 and 0.37 respectively) for all dates and all treatments. When adjusting for covariance of NDVI, the relationship between NDVI and GPP changed depending on the date (p__ .001) and treatment (p__ .029). Overall, these results demonstrate that NDVI values derived from ADC images can be related to ecosystem CO2 flux allowing for rapid evaluations of a specific area. However, the varying relationships between NDVI and physiological changes due to weather, date, or climate change scenarios need to be incorporated and calibrated for scaling efforts to be successful.

Climate impacts on alpine plant growth and reproduction: experiences from ten years of ITEX in Swedish Lapland

Ulf Molau

Botanical Institute, Göteborg University, Sweden

Tundra plants generally have long life-spans, and even though their flowering is prominent, reproduction is mainly by vegetative propagation within clones. Alpine vascular plants range in phenology from early-flowering "pollen riskers" to late-flowering "seed riskers", and the most stable among-year germinable seed output is maintained by species exhibiting an intermediate strategy. Within the International Tundra Experiment (ITEX), a number of ± circumpolar plant species, representing a wide range of life forms and phenological strategies, have been selected fore study. The majority of those species have been monitored at Latnjajaure in the high mountains in northern Swedish Lapland since 1993, including experimental temperature enhancement (2–3°C at surface) by Open-Top Chambers (OTCs) to simulate forecasted Climate Change. In addition, two of the main alpine plant communities in the northern Scandes, i.e., dry heath and mesic meadow, have been subjected to a factorial temperature and fertilizer treatment since 1995.

The results from these long-term studies show that flowering phenology is highly temperature-dependent in all alpine species. In the warming experiments, reproductive success in terms of seed weight increased significantly in all species except the arctic or nival specialists, e.g., *Saxifraga oppositifolia*. Most species also show a positive temperature response in vegetative growth; again the exceptions were evergreen arctic/nival species (e.g., *Cassiope tetragona*). This trend does, however, not apply across the entire life-form of evergreen dwarfshrubs: species with their distributional center in boreal woodlands, e.g., *Empetrum hermaphroditum* and *Vaccinium vitis-idaea*, responded most positively to the induced warming here at their upper distributional limit.

In several of the study species, the responses observed already after the first summer of experimental temperature enhancement have remained more or less stable through the 10-yr study period. The difference in leaf size measures between OTCs and control plots remains relatively constant in, e.g., *Dryas octopetala* and *Ranunculus nivalis*, whereas the control plots as ell as the OTCs show a steady increase in leaf size through the past decade, interpreted as a response to the observed ongoing climate warming the northern Scandinavia. Interestingly, plant growth measures are less noisy among years than are direct temperature measurements, and may serve as an excellent bio-indicator of climate change.

In acidic, nutrient-poor alpine tundra, reproduction of graminoids is mainly maintained by vegetative propagation at a low rate. Application of fertilizer rapidly induced flowering and a high sexual reproductive success already in the first treatment years, indicating a strong nitrogen limitation.

But these were all short-term responses, direct responses to environmental change that will stabilize during the first three treatment years. Community level responses are more indirect, mainly brought about by interspecific competition for resources, e.g., light, space, and nutrients. Results from across all ITEX sites show that climatic warming will favor deciduous dwarfshrubs, and nitrogen addition in poor heathlands favors the performance of graminoids. To detect such changes with statistical certainty in the species structure of alpine communities takes at least five years of continuous experimentation, and substituting time for space is not an adequate short-cut to achieve an adequate level of certainty in our ecological forecasting. The Global Change forecast for alpine areas includes not only increased temperature and a prolonged growing season, but also exponentially increasing atmospheric nitrogen deposition!

ITEX in Australia: An Integrated Assessment of the Impacts of Climate Change on Vegetation in the Victorian Alps'

Henrik Wahren
Research Centre for Applied Alpine Ecology/Dept. Agric. Sciences
La Trobe University, Bundoora, Australia

Climate change is potentially the most serious threat to Australia's alpine and sub-alpine ecosystems. Long-term climate and vegetation data suggest that our high mountain landscapes may already be changing in response to global climate change. This is of great concern because of the significance of these landscapes and because we currently lack much of the ecological knowledge necessary to predict, with confidence, how these landscapes are likely to respond to environmental change. Consequently, we urgently need to know how best to minimise the potentially undesirable effects of climate change in the Australian Alps and what methods can be used to influence or direct any changes that do occur to these rare landscapes. At this workshop I want to describe a project that addresses these needs, which was funded in May 2003 and will be set up in November 2003.

The project brings together a strong interdisciplinary group of scientists from several leading research laboratories, and the main Government agencies responsible for land management in the Victorian Alps. Our approach has been to integrate experimental ecology with genetics and ecological modelling. The main experimental component will use open-topped chambers and follow standard ITEX protocols. Genetic studies will use plants from within chambers, transplants, and from along an altitudinal gradient. This information will provide much of the empirical data to build species population models. Habitat and landscape responses will then be modelled by translating species-level responses predicted by the population models into landscape-level changes. The project has 4 main objectives:

- Examine experimentally the responses of a range of alpine and subalpine plant species to increased ambient temperature using open-topped chambers.
- Evaluate the genetic basis for survival and adaptive responses in selected alpine species.
- Model the ecological responses to climate change of specific alpine species, based on the empirical results and existing datasets.
- Develop a prognosis, based on the species models, for ecosystem responses to climate change in the main alpine plant communities, and the montane-subalpine, and sub-alpine - alpine interfaces.

Goose grazing and climate change impacts on the tundra: presentation of a new project in Adventdalen, Svalbard.

Elisabeth Cooper and Ingibjörg Jónsdóttir

The University Centre on Svalbard (UNIS)

UNIS is involved in Work Package 4 of the EU funded project 'FRAGILE': Fragility of Arctic Goose habitat: Impacts of Land use, conservation and Elevated temperatures.

The project focuses on the effects that increased goose grazing pressure has on tundra ecosystems in a context of climatic change. The population of geese on Svalbard has dramatically increased in the last decades, resulting in a growing concern that they will have a detrimental and non-reversible effect on the vulnerable Arctic tundra, as seen in La Peruse Bay in Canada. Goose herbivory selectively removes biomass thus changing the vegetation composition and the amount and quality of the litter produced. Goose droppings are a nitrogen source that increases forage productivity. Continued increase in the populations of geese grazing the tundra might have significant implications for both the carbon and nitrogen balance of the system.

Predictions of the extent of the effects of geese on these vulnerable ecosystems will be developed using results from a field experiment in Adventdalen. Treatments are applied to simulate a range of intensity of goose utilisation of the habitat. Interactions between goose density and climatic warming are investigated to determine the consequences of 1) increased goose grazing pressure in areas currently not grazed, and 2) increased local grazing pressure possibly leading to overgrazing, and 3) their interaction with climate change.

We aim:

- To identify and better understand the ecological processes which are most vulnerable to the combined drivers of high goose grazing pressure and climatic warming on High Arctic tundra vegetation.
- To describe the effects of goose grazing and warmer climate on on plant species composition, plant turnover and productivity, phenology and demography.
- To define thresholds for for arctic tundra ecosystem degradation on Svalbard.
- To predict carrying capacity of Svalbard tundra for geese, and potential effects of likely future goose populations.
- To contribute to the International Tundra EXperiment (ITEX), providing data on climate change effects for experimental sites throughout the Arctic using standardized methodologies.

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

Kari Klanderud and Ørjan Totland

**Department of Ecology and Nature Resource Management,
The Agricultural University of Norway**

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. We ask: 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 shoot growth and seed production under warmed (OTC) and fertilized conditions. We measure *Dryas* cover 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. Our results indicate that *Dryas* has a neutral to positive effect on other species in extreme Arctic environments, 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. Preliminary observations show that the highest germination frequency is in plots with a high frequency of bare soil and low vegetation cover, whereas few seedlings are observed in the dense *Dryas* mats. 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. Results indicate that biotic interactions from *Dryas* or any other vegetation impact growth and reproduction of *Thalictrum* and *Carex* at Finse, both alone, and in combination with warming and nutrient addition.

Plant and soil responses to neighbor removal and fertilization in acidic tussock tundra

M. Syndonia Bret-Harte, Erica A. García, Vinciane M. Sacré, Joshua R. Whorley, Joanna L. Wagner, Suzanne C. Lippert, and F. Stuart Chapin, III.

Institute of Arctic Biology, University of Alaska Fairbanks, U. S. A.

Studies in tundra at Toolik Lake suggest that the characteristics of the dominant plant species may affect the rates of biogeochemical cycling of carbon and nitrogen. For example, the shrub Betula nana becomes dominant in fertilized tussock tundra, leading to greater above-ground storage of carbon in woody biomass than in fertilized non-acidic tundra, where Betula is rare. To what extent do species characteristics affect ecosystem capacity to respond to perturbation, and the trajectory of response? If plant species coexist in tundra by partitioning soil nitrogen, can they use soil resources freed up by the removal of their neighbors? We removed single species and groups of species, in the presence and absence of fertilization, starting in 1997. After two years of treatment, vascular plants mostly responded positively to fertilization, but did not show many significant responses to neighbor removal. However, removal greatly increased soil nutrient availability, particularly in treatments that removed the most plant biomass. Whether plants will take advantage of increased nutrient availability over the longer term, or whether these nutrients will be lost from the ecosystem, remains to be seen.

Willow canopies and plant community structure along an alpine environmental gradient: a climate change impact assessment

Ørjan Totland[1], John Arvid Grytnes[2], and Einar Heegaard[2]

[1]Department of Biology and Nature Conservation, The Agricultural University of Norway, [2]Department of Botany, University of Bergen, Norway

Studies along natural environmental gradients may supplement experimental results on effects of climate change on plant community structure. We examined the impact of *Salix lapponum* canopies on plant community structure in five sites along a climatic gradient in a glacier foreland in alpine south-Norway. Species richness is lower inside canopies compared to outside in climatically relatively benign communities, while species richness is not affected by canopies in the most severe communities closest to the glacier. Differences in species composition inside and outside canopies, as judged by detrended correspondence analysis, are greater in the benign communities compared to the severe communities. Variation in the differences in species richness or composition outside and inside canopies within a community is related to differences in the reduction of photosynthetic active radiation (PAR) by canopies in only one community. Canopy size does not explain differences in species richness or composition between outside and inside canopies in any except one benign community. Our results suggest that species responses to canopies are individualistic, and that at the whole-community level negative and positive impacts of canopies on species occurrences cancel each other out in severe communities, whereas in benign communities negative effects dominate slightly over positive ones in their effects on species persistence inside canopies. Thus, if the density and/or size of willow canopies increase under climate change, this will likely have short-term antagonistic effects on community parameters, depending on the climate severity of the habitat before changes. Over longer time scales, increased density of willows will likely decrease species richness and have profound effects on community species composition.

Ecological Monitoring in the Arctic National Wildlife Refuge, Alaska

Janet Jorgenson, Colette Buchholtz, Bev Reitz, & David Payer

U. S. Fish & Wildlife Service
Fairbanks, Alaska

Between 1996 and 1999, Arctic Refuge biologists established a long-term ecological monitoring site in each of the five major ecological zones in the Refuge: boreal forest, forest-tundra transition, alpine tundra, coastal-plain tundra, and coastal marine. We monitor vegetation, small mammals, birds, terrestrial invertebrates, and physical parameters such as soils, permafrost, and weather. Objectives are to obtain baseline data, document trends, improve understanding of ecological relationships and natural processes, and contribute to regional databases.

Vegetation and environmental inventory and monitoring we have done include vegetation monitoring, plant inventory, plant phenology, air and soil temperatures year-round, coastal erosion monitoring, repeat of historical photography, ecological land classification, and investigations of site history by tree-ring counts, time sequences of aerial photographs, and fire history mapping.

We established intensive vegetation plots to be resampled every five years to track long-term trends in plant community composition. A plot is a transect of 10 1-meter-square quadrats in which plant species composition is quantified using the ITEX protocols. Each plot has been sampled twice; results have been summarized and will be presented.

Linking climate warming and pastoral land use change with shifts in plant community composition and biogeochemistry on the northeastern Tibetan Plateau

Julia A. Klein[1], John Harte[1], and Zhao Xin-Quan[2]

[1]University of California, Department of Environmental Science, Policy and Management, Division of Ecosystem Science, Berkeley, CA USA

[2]Northwest Plateau Institute of Biology, Chinese Academy of Sciences, Xining, Qinghai, PR China

Climate warming and pastoral land use change are global changes currently influencing the rangelands of the Tibetan Plateau. To examine the independent and combined effects of simulated climate warming and grazing on this alpine ecosystem, in 1997 we fenced four 30x30m sites which were distinguished by habitat, season of use and grazing intensity history. Within each site, we established a complete factorial experimental design with four-fold replication. We simulated warming using conical open top chambers (OTCs) and simulated the defoliation effects of grazing through selective clipping.

OTCs consistently elevated growing season-averaged mean 24 hour air temperature by 1-2°C at 10cm aboveground. The OTC effect on growing season-averaged soil temperature was inconsistent among sites and years and varied in the presence or absence of clipping. OTCs either had no effect or increased soil temperature by 0.5-2.0°C at 12cm depth.

OTCs had strong effects on vegetative community composition and aboveground net primary productivity (ANPP). OTC warming decreased total species richness (SR) by 5-15 species; decreases in SR occurred by the second year of the study and were relatively insensitive to the presence or absence of clipping. Other indices of diversity, such as Simpson and Shannon, similarly declined with warming. At the meadow sites, OTC warming decreased total ANPP by approximately 60g/m^2/yr; this effect was generally independent of the presence or absence of clipping. At the shrubland sites, the OTC effect on total ANPP depended on the presence or absence of clipping and also on site grazing intensity history. OTC warming on a non-clipped landscape decreased total ANPP by 30g/m^2/yr at the low grazing intensity history (LG) site and had no effect on total ANPP at the high grazing intensity history (HG) site. By contrast, warming on a clipped landscape had no effect on total ANPP at the LG site and increased total ANPP by 40g/m^2/yr at the HG site. These site differences in total ANPP response to OTC warming can be explained in part by vegetation group responses to warming. Graminoid ANPP decreased while shrub ANPP increased with OTC warming; forb ANPP responded individualistically to warming. We discuss some of the potential mechanisms responsible for these vegetative changes.

While OTC warming had strong effects on vegetation, OTC warming had comparatively weak effects on soil properties and processes. For example, there was no significant treatment effect on the total soil carbon pool over the duration of our experiment. However, controlled laboratory incubations revealed decreases in the labile soil carbon pool with warming. Based on the OTC-induced vegetative group changes, and how these groups vary with respect to traits such as leaf litter lignin: nitrogen ratios, we predict significant future changes to the soil carbon pool with warming. These changes will be due to the indirect effects of warming as mediated through the vegetation changes we have observed.

Alaskan Landscapes: Education Outreach through Research

Cynthia L. Williams

Institute of Arctic Biology, University of Alaska Fairbanks,

The **Alaskan Landscapes Education Outreach Project** is developing a suite of interactive multimedia computer programs about UAF research and about the relationships between that research and management of our natural resources. Our broad objective is to use interior Alaskan landscapes to teach K-12 students and the general public how we learn about and make decisions about management of our natural resources.

Five modules are under development: **Wondering about Alaskan Landscapes, Seeing Alaskan Landscapes, Understanding Alaskan Ecosystems, Research in Alaskan Landscapes, Decision-making for Alaskan Landscapes.** *I present them here to invite collaboration and participation in further development of this project. This is an opportunity for researchers to explain clearly to the general public and to school children who we are, why we study what we do, and how we hope the information will be used. This project will demonstrate the breadth of research contributing to management of our natural resources in interior Alaska, and will show how research results are actually used. The initial focus has been on teaching about how scientific research works, and on teaching scientific method, ecology, and remote sensing through specific local research about natural resources.*

The **Research in Alaskan Landscapes** module serves to illustrate how the five modules function. It highlights the multiplicity of ways in which a user can learn about scientific research and researchers. The Interior Alaskan landscape is the central organizing scheme. As the main menu, research sites are highlighted on basemap images of the Interior Alaskan landscape near Fairbanks. These research sites are active links, but the type of information they link to depends both on the user's choices and on input from individual researchers. Research sites provide links to scientists, ecosystems, species, research questions, timelines, scales of study, seasonal research, models and simulations, global change science, global processes, and agency-UAF collaborations. Users choose their own trajectories through this material, with cross-links connecting different organizational threads. This Research module will likely be the largest component of the final project. The Research module teaches about how scientists answer our questions about landscapes. However, people can't really understand how science works and contributes to decision-making without understanding the roles of questions and perspectives in science.

The four other modules will examine our different perspectives and values, how we arrive at them, what questions we ask, and how we combine all of these factors in decision-making. These are intended to increase user awareness of different perspectives and values, to improve public communication for future decision-making, to build public understanding of how UAF research contributes to decision-making and planning for the future, and to teach how diverse fields of inquiry contribute to decision-making. Other components of the project are designed to stimulate thinking about our landscapes and landscape processes, to teach basic ecological principles and to teach basic knowledge and skills with satellite-based remote sensing technologies.

An update on a Circum-Arctic Environmental Observatories Network (CEON)

Craig E. Tweedie*, Patrick J. Webber & Robert D. Hollister

Michigan State University, East Lansing, MI , USA.
corresponding author: 100 North Kedzie Hall,
Michigan State Universit,East Lansing, MI48824, USA.
tweedie@msu.edu,

The concept of a terrestrial Circum-arctic Environmental Observatories Network (CEON) was introduced at Arctic Science Summit Week (ASSW) in 2000 at a meeting of the Forum of Arctic Research Operators (FARO: www.faro-arctic.org). CEON is conditioned by the need for increased international integration of research effort and the loss and/or danger of loss of continuous northern high latitude environmental observations. FARO has endorsed the CEON concept advocating that CEON be developed to promote environmental measurements and dissemination of these to Arctic researchers whilst encompassing and building on the strengths of existing arctic stations and environmental observatory networks. Since 2000, the CEON concept has increasingly received enthusiastic support from a variety of existing networks, disciplinary collaborations and research stations as well as endorsement from the the International Arctic Science Committee (IASC) (www.iasc.no).

At ASSW 2002, a working group was formed to scope and develop the concept of CEON. Since then, presentations of the CEON concept have been made at meetings of various networks, research collaborations and polar research boards in Europe, Russia and the United States in order to make contact and collect feedback from potential CEON stakeholder and user groups. Presentations have focused on the necessity for the CEON initiative to meet and promote the needs of the participating research community, science administrators, policy makers, industry, education and indigenous communities. In doing so, it has been stressed that CEON should be seen as a network that facilitates and encourages environmental monitoring, which provides linkages between disciplines and existing networks and connectivity spanning regional to circumarctic and global scales. Following CEON presentations audiences have been asked to introduce their own bias in the development of CEON by providing feedback to the following question: "***What would you do if you had the opportunity to conduct standardized long term, integrated measurements across all research stations and networks in the Arctic?***" It is hoped that this approach will facilitate the development and scope of CEON based on the experience, needs and future directions envisaged by a broad range of potential CEON stakeholder and user groups.

The CEON initiative should not be seen as duplicating prior or ongoing research effort, but an international partnership that aims at forming a logistic and research framework within which ongoing and future research can be oriented to cumulatively form and facilitate long-term research endeavors in the Arctic. Based on recent scoping and development activities and the convention of the first planning meeting in October 2003, this presentation recapitulates the enthusiastic support for the initiation of CEON and outlines a conceptual roadmap for its inception. This road map will include the formation of an interim multidisciplinary and international steering committee, an international workshop and a science implementation strategy. We invite your thoughts and ideas to facilitate the development of the CEON initiative.

Poster Abstracts

Evidence for local adaptation to climate? The evolutionary dynamics of leaf bud dormancy in balsam poplar

Amy Breen Carroll [1,2], Matthew Olson [1,2] and Marilyn Walker [2,3]

Institute of Arctic Biology [1], University of Alaska Fairbanks [2] and US Forest Service Pacific Northwest Research Station [3]

The goal of the International Tundra Experiment (ITEX) is to better understand species-level responses of arctic vegetation to climatic change. Species-level responses to climatic change include acclimation, adaptation, extinction or dispersal to more favorable environments. Although both acclimation and adaptation result in persistence, these two processes differ significantly. Acclimation is a short-term phenotypic response to a plant's local environment. In contrast, adaptation is the evolutionary response of a plant population to natural selection. Ultimately, long-term persistence is dependent upon capacity for adaptation to climatic change.

Our research employs a population genetics approach to assess the capacity for adaptation to climatic change in the model organism, balsam poplar (*Populus balsamifera*). Balsam poplar is a common forest tree throughout central and southern Alaska. In addition, balsam poplar occurs in isolated stands in the otherwise treeless Arctic in the northern foothills of the Brooks Range. Climatic conditions, and subsequently selective regimes, vary widely across this latitudinal gradient. This amazing breadth offers an unparalleled opportunity to study past adaptation to climate to infer capacity for future evolutionary change.

Growth and biomass allocation of *Alopecurus borealis* and *Dupontia* spp. following simulated goose grazing

Dominique L. Chaput[1], Elisabeth Cooper[2], Ingibjörg Jónsdóttir[2]

[1]University of Oxford, [2]The University Centre on Svalbard (UNIS)

This study aimed to assess the impacts of grazing on the productivity and biomass allocation of *Alopecurus borealis* and *Dupontia spp.*, common High Arctic graminoids. A clipping experiment was conducted in Adventdalen, on Svalbard (78°N), in June-July 2003. Plants were clipped once (early or late), twice, or not at all. Growth of individuals was followed, and plants were harvested regularly for biomass allocation measurements. Clipping did not affect cumulative leaf elongation. In both species, clipping consistently increased the ratio of live above-ground to below-ground biomass, but this trend was not statistically significant. Total biomass of *A. borealis* was not affected by clipping, but total biomass was lower in all clipped *Dupontia spp.* groups at the end of the experimental period ($p=0.005$). Therefore, despite losing photosynthetic tissue through clipping, both species maintained their growth rate, but possibly at the expense of below-ground biomass. Grazing, by depleting resources needed for early-season growth, may therefore have a greater impact on productivity in subsequent years. In addition, by forcing plants to tap into stored carbon rather than rely on photosynthesis, grazing on a large scale may alter ecosystem carbon fluxes.

Using Ordination to relate Climate and Previous Investment Measures to Low-Arctic Plant Phenology, Growth and Reproduction

Karin M. Clark and Greg Henry

University of British Columbia
Department of Geography
Vancouver, Canada

As part of the International Tundra Experiment, eight plant species in the Canadian low-arctic have been monitored from 1997 to 2002 for phenology, growth and reproductive investment. The eight study species are *Oxytropis nigrescens*, *Ledum decumbens*, *Vaccinium vitis-idaea*, *Betula glandulosa*, *Salix* spp., *Saxifraga tricuspidata*, *Eriophorum vaginatum* and *Carex aquatilis*. Relationships between climate, previous year's investment and plant responses are analyzed through the use of a linear ordination technique, Canonical Correlation Analysis.

Results show that thawing degree days (a measure of heat accumulation) proved to be the predominant climatic influence on time to leaf out (in deciduous plants) and time to flower in most species. Incoming global solar radiation was the primary influence on time to flower in two species. Thawing degree days was also the predominant influence on growth and reproductive investment in most species. However, in two species, the primary influence on current growth and reproductive investment was investment from the previous year.

Many species showed interesting relationships between previous and current year's growth and reproductive investment. Surprisingly, some also showed relationships between previous year's investment and currents year's phenology.

Metadata, Long-Term Archiving and Arctic System Science (ARCSS) Data Coordination Center (ADCC) Management Services.

R. J. Dichtl, C. McNeave, N. Auerbach E. Sheffield

National Snow and Ice Data Center, University of Colorado, Boulder, CO

The ARCSS Data Coordination Center (ADCC) at the National Snow and Ice Data Center (NSIDC), University of Colorado at Boulder, is the permanent, long-term data archive for all components of the ARCSS Program. Funded by the National Science Foundation's Office of Polar Programs, our focus is to archive and provide easy access to ARCSS-funded research data and information. The concept of System Science research depends on the accessibility and exchange of data and information within the scientific community. The ADCC strives to be a catalyst to facilitate that accessibility and synergism. Metadata is a significant ingredient in insuring the long term usefulness of data archived on our Web site.

A major concern of the research community is the availability of reliable data for research. Working directly with ARCSS investigators, the ARCSS Committee and NSF, the ADCC is continually acquiring data and developing metadata products appropriate and useful for long-term

archival of these research data. Integration of the data and the associated metadata from ARCSS projects as described on this poster is a high priority at the ADCC.

Metadata is the "who, what, where, when, why and how" of data sets and are crucial to an investigator looking for suitable data to answer specific research questions. Metadata comprise information about the data, and preserve the usefulness of the data over time. Preparation of complete metadata is the primary requisite for all long-term archiving activities at ADCC.

The ADCC home page (http://arcss.colorado.edu) has become an important tool for data accessibility and integration within the ARCSS program.

Plant-herbivore interactions in relation to snowmelt in the High Arctic

Christiaane Hubner

The University Centre on Svalbard, Norway

The poster introduces a PhD-project on interactions between migrating geese and plants in the high Arctic during spring. The time when geese migrate to the Arctic is relatively constant, whereas the time of snowmelt is very variable between years. Consequently, plant phenology and, thus, food availability for geese during spring is strongly influenced by the timing of snowmelt. For plants, the impact of goose grazing depends on intensity and timing of the event. For geese, however, feeding conditions in spring are suggested to be crucial for their breeding success and, hence, influence population dynamics. Global change may alter the phenology for both, goose migration and plant growth, and thus, alter their relationship. Accordingly, only by examining the phenology of geese and plants, mechanisms controlling this relationship can be fully understood. Consequently, this study involves (1) an examination of goose feeding habits in a pre-breeding area for geese in Svalbard, Norway, (2) an assessment of forage impact on the vegetation, by experimental altering the timing and intensity of the grazing, and (3) an evaluation of the consequences of feeding conditions for the reproductive performance of the geese.

Vegetative Recovery Following the 1988 Waring Mountains Fire In Northwest Alaska: 1989-1998

Joan Foote

Denali Institute, Denali Park, Alaska

The Waring Mountains Wildfire of 1988 burned 84,727 ha of the Selawik National Wildlife Refuge in northwest Alaska. This burn transected the migration route of the Western Arctic caribou herd. Disruption of the movement of caribou through this area was of major concern due to the large number of people dependent on these animals for subsistence. This study was undertaken to describe and follow the response of the vegetation after the fire. Sites representing four widely distributed vegetation communities were selected for study: Dry Shrub-Sedge Tundra, Moist Shrub-Sedge Tundra, Low Shrub-LichenTundra and Open Black Spruce Forest. Sites were inventoried 1,2,3, and 10 years following the fire.

Tracking surrogates for intraspecific biodiversity: Towards efficient selection strategies for the conservation of natural genetic resources using comparative mapping and modelling approaches – a project preview

Felix Gugerli

Swiss Federal Research Institute
Birmensdorf, Switzerland

Species richness is the most widely used measure for biodiversity assessment. However, it is intraspecific diversity (genetic polymorphism) that represents the evolutionary and adaptive potential of each species in changing environments. We propose to study possible correlations between intraspecific diversity and species richness or habitat variation.Using the Alps and the Carpathians as model systems, we will ask: (i) Is there a congruence between biodiversity at the intra- and interspecific level? (ii) Do areas of high endemism, often coinciding with glacial refugia, harbour a great partition of the intraspecific diversity? (iii) Is habitat variation, characterised by environmental parameters, a good surrogate for intra- and interspecific diversity? On a regular grid cell system, we assess intraspecific variability for 25 species (three individuals per grid cell) using amplified fragment length polymorphisms (AFLP), compile existing data on species occurences, which will also result in distribution maps of ca 1300 alpine taxa, and model environmental diversity using biophysical data sets, e.g. elevation, inclination, geology, soil, precipiation, etc. Based on modelling and simulation techniques, we will develop a web-based public platform for efficiently selecting nature reserve networks which comprise the highest proportion of both intra- and interspecific diversities. Our integrative approach should help to better understand and predict ecosystem patterns on a large scale. The established platform will provide an innovative and efficient technology for observing and managing biodiversity.

Ice sheet history of the Eurasian North reflected in genetic variation of arctic plants

Ingibjörg Jónsdóttir[1], Ólafur Ingólfsson[1], Ingibjörg Svala Jónsdóttir[1] & Anna Stenström[2]

[1]The University Centre on Svalbard, Norway.
[2] Department of Botany, Göteborg University, Göteborg , Sweden

Recent efforts under the international QUEEN programme (Quaternary Environments of the Eurasian North) have defined, mapped and dated ice-marginal zones across the Russian high arctic, from the White Sea area in the west to the Taimyr Peninsula in the east, for highlighting the ice sheet history during the last > 150,000 years. The program defines four periods with extensive glaciations: (1) A Late Saalian glaciation (older than 130,000 years) was one of the most extensive glaciation during the Quaternary, with immense areas in Eurasia covered by huge glaciers; (2) An extensive glaciation during the Early Weichselian (ca. 90,000 years ago); (3) successively smaller glaciations during early Middle Weichselian (60-50,000 years ago) and (4) the Late Wichselian (21-18,000 years ago). The Early Weichselian glaciation covered the coastal northern Russia and western Siberia and extended eastwards over the Kara Sea and the Yamal and Taimyr peninsulas, whereas later, during the Middle and Late

Weichselian glaciations, the centre of glaciation shifted westwards and areas east of the Kara Sea basin were mostly ice-free.

A separate study of the structure of genetic variation within and among populations in four closely-related arctic clonal sedges was carried out on a west-east transect along the northern Russian and Siberian coast during the Swedish-Russian Tundra Ecology-94 Expedition. The sedges studied were *Carex bigelowii, C. ensifolia* ssp. *arctisibirica, C. lugens* and *C. stans*. The studied taxa all had high levels of genetic variation, both within populations and taxa. Genetic variation observed could not be related to any tested environmental variable, but showed significant correlation to the length of time each area had been ice free: the highest genetic variation was found in populations growing in the easternmost areas, that were ice free throughout the last glacial cycle, and the lowest variation occurs in populations growing along the coast of the Arctic Ocean in Northern Russia, in areas glaciated or in close proximity to ice sheets during the Middle and Late Weichselian.

Wolf Creek, Yukon ITEX Site Report and Issues

Val Loewen[1], Joan Eamer[2], and Mike Gill

[1]Environment Yukon
[2]Canadian Wildlife Service, Environment Canada

The study site is located in the alpine zone within the Wolf Creek drainage basin, within approximately 1 km of the Wolf Creek alpine climate station. The site has a SSE aspect and a shallow slope (estimated at 3-5°) and is characterized by a relatively homogeneous vegetation community dominated by mat-forming shrubs (*Dryas octopetala, Salix arctica* and *S. reticulata*), lichens (*Alectoria* spp., *Cetraria* spp.), *Festuca altaica* and *Lupinus arcticus*. Soils are relatively dry (submesic to subxeric), with a high gravel and rock component, little to no humus development, and frequent bare areas caused by active frost boils.

An experimental warming experiment was established in 1998. Experimental plots (n=10) consisted of rectangular 1.1 x 2.4 m open-topped greenhouses and unmanipulated controls (n=10). After several years, when warming was not apparent in the greenhouses, they were replaced in 2001 with the "standard" ITEX circular open-topped design.

Measurements at the site include:

- Soil and air temperature
- Relative humidity
- Detailed plant community composition
- Peak season growth for *Salix arctica, Lupinus arcticus, Dryas octopetala* and *Polygonum viviparum.*
- Density of reproductive structures by species

(cont'd next page)

(Loewen, Eamer, and Gill, cont'd)

Some issues concerning the measurements include:

- *Salix* – male and female representation in the sample size (very few males)
- Frequent loss of tags and mortality of focus plants; how to recruit new individuals?
- Ensuring same plant is measured each year - "moving" or lost tags, accurate recording of plant location in plot.
- *Dryas* flower counts – determining flowers in seed set
- What flower structures to count on each species - individual flowers/fruits or stalks with multiple flowers?
- Timing of flower counts and plant measurements – impacts of phenologic differences between species
- Sample size

Preliminary results do not indicate any differences between experimental and control plots. Results can be seen on the poster by D. Bean and G. Henry entitled: *Climate Change Impacts on Tundra Ecosystems: The CANTTEX Network of Ecological Monitoring Sites in the Canadian Arctic.*

Beyond warming: the importance of changes in snow cover

Christian Rixen[1,2], Sonja Wipf[1,2] and Veronika Stoeckli[2]

[1]Institute of Arctic Biology, University of Alaska Fairbanks [2]Swiss Federal Institute for Snow and Avalanche Research SLF, Davos, Switzerland

Changes of the snow cover have not been addressed in many arctic and alpine warming experiments or they have been confounded with other factors.

We investigated vegetation changes in reaction to changes in the snow cover on 38 Swiss ski runs with two different kinds of snow: compacted natural snow with a thin and dense snow cover and compacted artificial snow with a deep and dense snow cover. Plots on ski runs were compared with ambient plots beside the ski runs. The compacted natural snow resulted in hard soil frost but not in a delayed time of snowmelt whereas the artificial snow resulted in moderate winter soil temperatures but a delayed snowmelt.

Plant species from wind edges were increased on the ski runs with natural snow whereas species from snowbeds were increased on the ski runs with artificial snow. Early-flowering species were decreased and late-flowering species increased on both kinds of ski pistes compared with the ambient plots.

These results show how changes in the snow cover can result in vegetation changes of specific ecological species groups. The impacts of the snow cover were complex in a sense that different snow properties caused different vegetation changes: extreme winter temperatures under a thin snow cover favored windedge species and a late snowmelt under a deep snow cover favored snowbed species. However, both factors probably narrowed the niche of early-flowering species in favor of late-flowering species. This study points out the importance of snow cover characteristics for warming experiments in the arctic and alpine environment.

The interactive effects of three global stressors on the growth morphology and chemistry of sugar maple (*Acer saccharum*) seedlings growing on soils of contrasting chemistry.

Eric Sager and Tom Hutchinson

Trent University, Peterborough, Ontario, Canada

The interactive effects of springtime warming, UV-B, and nitrogen fertilization (equivalent to an additional 50 kg N ha^{-1} yr^{-1}) on the growth and chemistry of sugar maple (*Acer saccharum*) seedlings from two contrasting sugar maple forest sites in central Ontario were assessed. The soils of the Oliver forest were deep luvisols overlying a strongly calcareous till, while the naturally acidic soils of Haliburton were derived from the Precambrian Shield. Warming significantly altered the carbon and nitrogen dynamics of the soils and significantly reduced the leaf area of individual sugar maple seedlings at both sites. Removal of ambient levels of UV-B led to increased foliar concentrations of some flavonoids and chlorogenic acid at both sites and appeared to be responsible for a significant reduction in herbivore activity. At Haliburton, nitrogen additions led to increased foliar concentrations of Mn and decreases in the concentration of measured phenolics and flavonoids, while at Oliver forest nitrogen led to increased concentrations of Mg and chlorogenic acid and decreases in some flavonoids in leaf tissues. This implies that there is a potential interaction between the acid sensitivity of these soils and the secondary chemistry of the plants growing in the soils.

The Barrow Area Information Database - Internet Map Server (BAID-IMS)

Craig E. Tweedie[1*], Allison Graves[2], David Zaks[1] and Shawn Serbin[1].

[1]Arctic Ecology Laboratory, Michigan State University,
[2]Nuna Technologies, PO Box 1483, Homer, AK 99603, USA
***Corresponding author tweedie@msu.edu**

The Barrow Area Information Database - Internet Map Server (BAID-IMS) is a prototype project that has been developed under the emerging Spatial Data Infrastructure (SDI) activities coordinated by the Digital Working Group (DWG) of the Barrow Arctic Science Consortium (BASC). As well as remote sensing products, topographic maps and current research information, BAID-IMS contains information about historical research conducted in the Barrow area in northern Alaska dating back to the 1940's. This information is used freely and interactively by researchers, land managers, educators and the local community to access spatial data and information on terrestrial, marine, freshwater and atmospheric research in the Barrow area. The Barrow area in this application is defined as the region encompassed between the North Slope village of Barrow in the North to Teshekpuk Lake in the East to the villages of Atqasuk in the South and Wainwright in the West. All information in this application is accompanied by metadata that meets the standards of the Federal Geographic Data Committee (FGDC) and it is hoped that data will be available for downloading at The Arctic System Science (ARCSS) Data Coordination Center (ADCC) at the National Snow and Ice Data Center (NSIDC) located at University of Colorado in Boulder, USA. BAID-IMS was developed by the Arctic Ecology Laboratory at Michigan State University and Nuna Technologies under contract to BASC who is supported by the Office of Polar Programs (OPP) at the National Science Foundation (NSF).

CEON: A Circum-Arctic Environmental Observatories Network

Craig E. Tweedie*, Patrick J. Webber

Michigan State University, East Lansing, MI, USA
***Corresponding author tweedie@msu.edu**

The concept of a terrestrial Circum-arctic Environmental Observatories Network (CEON) was introduced at Arctic Science Summit Week (ASSW) in 2000 at a meeting of the Forum of Arctic Research Operators (FARO: www.faro-arctic.org). CEON is conditioned by the need for increased international integration of research effort and the loss and/or danger of loss of continuous northern high latitude environmental observations. FARO has endorsed the CEON concept advocating that CEON be developed to promote environmental measurements and dissemination of these to Arctic researchers whilst encompassing and building on the strengths of existing arctic stations and environmental observatory networks. Since 2000, the CEON concept has increasingly received enthusiastic support from a variety of existing networks, disciplinary collaborations and research stations as well as endorsement from the International Arctic Science Committee (IASC) (www.iasc.no).

At ASSW 2002, a working group was formed to scope and develop the concept of CEON. Since then, presentations of the CEON concept have been made at meetings of various networks, research collaborations and polar research boards in Europe, Russia and the United States in order to make contact and collect feedback from potential CEON stakeholder and user groups. Presentations have focused on the necessity for the CEON initiative to meet and promote the needs of the participating research community, science administrators, policy makers, industry, education and indigenous communities. In doing so, it has been stressed that CEON should be seen as a network that facilitates and encourages environmental monitoring, which provides linkages between disciplines and existing networks and connectivity spanning regional to circumarctic and global scales. Following CEON presentations audiences have been asked to introduce their own bias in the development of CEON by providing feedback to the following question: "***What would you do if you had the opportunity to conduct standardized long term, integrated measurements across all research stations and networks in the Arctic?***" It is hoped that this approach will facilitate the development and scope of CEON based on the experience, needs and future directions envisaged by a broad range of potential CEON stakeholder and user groups.

The CEON initiative should not be seen as duplicating prior or ongoing research effort, but an international partnership that aims at forming a logistic and research framework within which ongoing and future research can be oriented to cumulatively form and facilitate long-term research endeavors in the Arctic. Based on recent scoping and development activities and the convention of the first planning meeting in October 2003, this presentation recapitulates the enthusiastic support for the initiation of CEON and outlines a conceptual roadmap for its inception. This road map will include the formation of an interim multidisciplinary and international steering committee, an international workshop and a science implementation strategy. We invite your thoughts and ideas to facilitate the development of the CEON initiative.

Effects of climate warming on activity of the soil-borne plant pathogens in the moss on Svalbard: Introduction of a new experiment

Masaki Uchida

National Institute of Polar Research , Tokyo, Japan

Many dying moss colonies were found in the moss carpets of *Sanionia uncinata* in Svalbard. In previous results suggested that some soil borne plant pathogens were involved in dying of the moss. Climate warming may enhance their activity and lead to dying of moss on Svalbard. Purpose of this study is to clarify effects of climate warming on activity of the soil borne plant pathogens in the moss on Svalbard. The fungal diversity and disease development will be evaluated in every summer from 2003 to 2007 under open top chamber conditions in the fields.

Intraspecific variation in the ecophysiological characteristics of a common feather moss, *Hylocomium splendens*

Takeshi Ueno

National Institute of Polar Research , Tokyo, Japan

Hylocomium splendens, a widespread feather moss, is one of the major plant species found in the arctic tundra. It occupies various habitats ranging from exposed dry grounds to swampy grounds. To reveal the ecophysiological characteristics of *H. splendens* growing in different water conditions, the relationship between photosynthetic and respiratory rate and tissue water content in contrasting water conditions, i.e. dry site (moraine), moist site (outwash terrace) and wet site (stream edge), was investigated. Optimum water content for photosynthesis was different among sites. The value of *H. splendens* growing in dry site, moist site and in wet site was ca.350%, 400% and 450% dry weight, respectively. The respiratory rate of *H. splendens* growing in dry site declined more steeply in relation to the decreasing water content of the plant tissue than that of *H. splendens* growing in moist and wet sites. These results and their ecological significance are discussed.