

Niwot Ridge LTER 1993 Research Workshop

21 August 1993

Agenda

0830 Coffee and Carbos; Poster Set-ups

0850 Introductions and Workshop Overview

Session 1.

0915 Nitrogen and Nitrogen Saturation in Alpine Ecosystems.

1045 **Poster Session I.** (*and coffee*)

Nitrogen Dynamics in Alpine Tundra.

1130 Discussion: Suggestions for New Measurements in the Subnivean Access Studies.

1215 Lunch

Session 2.

1300 Landscape Perspectives Needed to Understand the Alpine Tundra.

1400 **Poster Session 2.** (*and coffee*)

Landscape Studies in the Alpine Tundra.

1430 Discussion: A 100-year experiment to examine long-term ecological effects of altered snow regimes to alpine ecosystems.

Discussion: Regionalization. What is it and what do we want to do about it?

1515 Adjourn

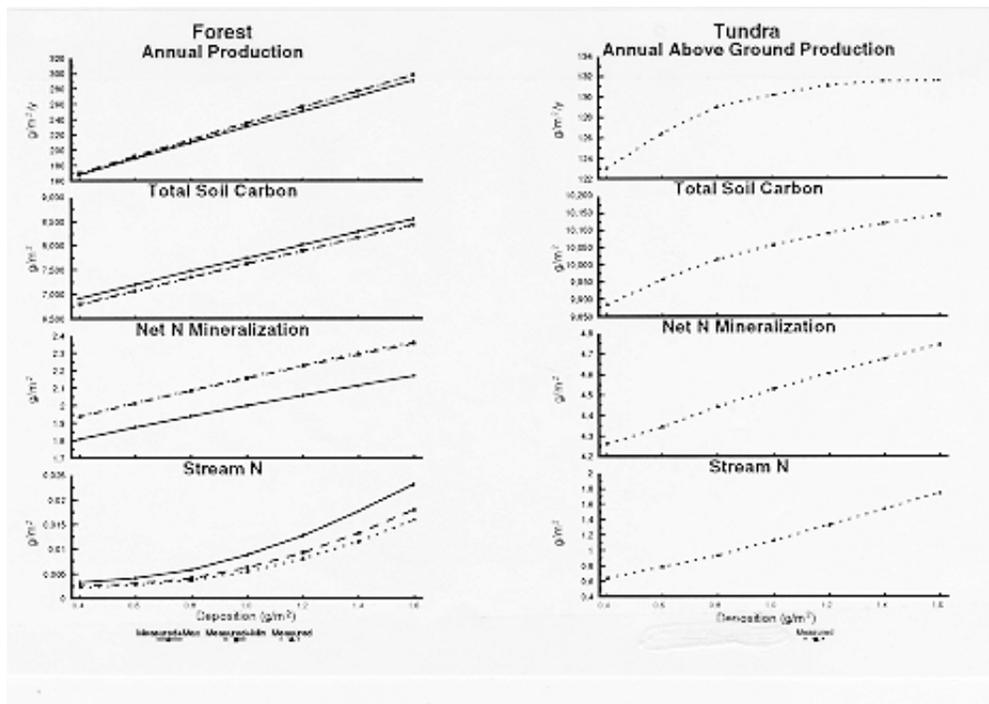
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Sources and Sinks of N Species in High Elevation Rocky Mountain Ecosystems

Jill Baron, Dennis S. Ojima, Elisabeth A. Holland, William J. Parton

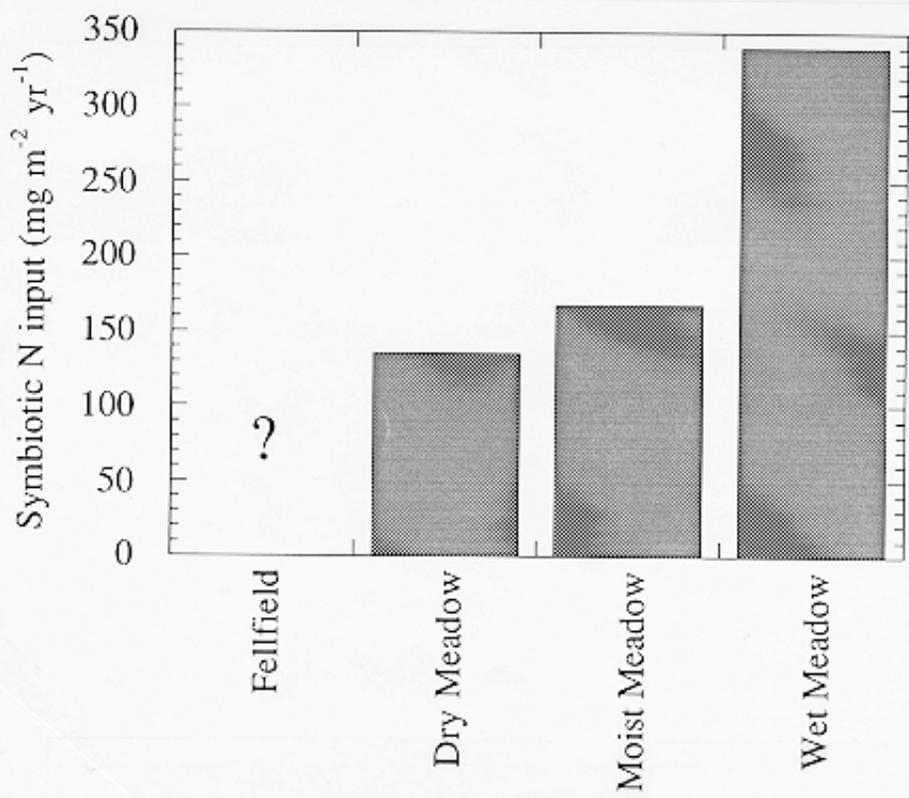
Poster Abstract. We are exploring processes that affect nitrogen cycling in the Loch Vale Watershed by combining biogeochemical data from the past 9 years with the CENTURY ecosystem process model. Our results, shown in **Figure 1**, suggest: 1. Tundra behaves conservatively with respect to N fluxes. Virtually all N that enters via deposition is passed through the tundra into streams. The stream response to increased N deposition is a nearly linear increase in N concentration; 2. The ability of tundra to accommodate increased N is very low. Above ground production increases by only 8 g C m⁻² y⁻¹ even when N deposition increases four-fold; 3. Subalpine forest consumes virtually all incoming N, and annual forest production increases linearly with a linear increase in N deposition; 4. The strong forest response to increased N results in extremely low loss rates from forest soils to streams. While leaching increases with increased N deposition, the actual increase is only 0.01 - 0.02 g N m⁻² y⁻¹.



Symbiotic Nitrogen Fixation by Three Alpine *Trifolium* Species

William D. Bowman, James C. Schardt, Steven K. Schmidt, and Brian Thomas

Talk Abstract. Three *Trifolium* species constitute from 1 to 20% cover in four alpine plant communities in the Colorado Front Range. Symbiotic N-fixation by these clover species may thus contribute significantly to intersystem N inputs in the alpine. We measured N stable isotope composition in the *Trifolium* species and in non-fixing adjacent reference plants to estimate the contribution of atmospherically fixed N to the N budgets of the *Trifolium* plants and the communities that make up the Niwot Ridge alpine ecosystem (**Figure 2**). Nitrogen-fixation contributed between 50 to 100% of the N budgets of the *Trifolium* plants, with the highest estimates in the dry and wet meadow plants. At the community level inputs from N fixation ranged from 135 mg m⁻² yr⁻¹ in the dry meadow to 340 mg m⁻² yr⁻¹ in the wet meadow. Estimates of N-fixation could not be made for the fellfield using the N stable isotope technique, but inputs would potentially be greater than the other communities, as *Trifolium* cover is at least four-fold greater than the other communities. Symbiotic N-fixation is a relatively large intersystem contribution of N into alpine tundra, but the inputs are spatially heterogeneous, corresponding with large patches of *Trifolium*, that significantly impact the spatial nature of species composition and production.



Preliminary Information on Winter/Spring Nitrogen Cycling in the Colorado Alpine

Paul D. Brooks, Mark W. Williams, and Steven K. Schmidt

Talk Abstract. Inputs, outputs, and fluxes of nitrogen were followed from October 1992 through June 1993 at Niwot Ridge in the Colorado Front Range. Concentrations of soil and snow inorganic nitrogen were measured monthly from January to March, biweekly through April, and weekly until the first of June. Temporal variability in nitrogen inputs from precipitation to tundra soils were estimated from ion exchange resins harvested in mid-winter and at the end of the snow covered season. Nitrogen outputs from the system through leaching were estimated using ion exchange resins at a depth of 10cm. Gaseous losses as N₂O were measured at two sites on the tundra and one just below treeline. Soil inorganic nitrogen concentrations were highest in January when tundra soils were completely frozen. Concentrations decreased rapidly as soils under the snowpack warmed above -5C. As snow depth decreased in the spring, concentrations again increased presumably due to freeze/thaw cycles. Significant concentrations of CO₂ under the snowpack, suggesting microbial activity, were first observed in early March. Nitrous oxide production under snow was first observed in April, corresponding to soil temperatures above -3C. These data suggest that the insulating effect of snow cover during the long alpine winter may allow soil microbial activity during this season to significantly affect the N cycle in these systems.

Nitrogen and Lignin Controls on Decomposition in Alpine Tundra. I. Theoretical and Model Predictions

David M. Bryant, Elisabeth A. Holland, Timothy R. Seastedt

Talk Abstract. The respective roles of nitrogen and lignin in soil organic matter dynamics was explored through literature and modeling investigations. Literature surveys indicate that nitrogen cannot be limiting to decomposition processes as long as C:N ratios remain at or below values of about 20 (ca. 2% or more nitrogen). Initial high nitrogen concentrations are hypothesized to subsequently reduce decomposition rates, although the mechanisms explaining this response are largely speculative. Lignin values have a uniformly negative relationship with decomposition rates in all studies investigated. The CENTURY model "microcosm" version was used to evaluate nitrogen and lignin controls over the range of temperature and precipitation values likely to be encountered in alpine tundra. Lignin appeared to be relatively more important. Nitrogen content of litter appears relatively invariant relative to other ecosystems.

Spatial Patterns of Summer Precipitation in an Alpine Environment

Nel Caine, John C. Iott, and Brian P. Menounos

Talk Abstract. In 1992 and 1993, summer precipitation was being measured by a network of 35 storage raingauges in a 550 m grid over the Green Lakes Valley. In the summer months of 1992, precipitation totalled about 250 mm in the basin and showed little spatial pattern and no elevational effects (Table 1). When totals for June, July, and August are treated separately, weak spatial patterns reflecting north-south contrasts rather than elevational influences are evident (Table 1). Predictably, individual storms yielding more than 8 mm of precipitation are more variable in space. Correlations of storm totals with elevation are usually significant but inconsistent in sign (Table 1). Semivariograms of storm depths suggest a range of 2.5 to 3.0 km and are improved when the drift due to elevation is removed from the original data. This suggests that areal mean precipitation amounts in summer may be empirically estimated by a model equivalent to that defined by Chua and Bras (1982) for winter storms in the San Juan Mountains. [Chua, S.H., and R.L. Bras. 1982. *Optimal estimators of mean area precipitation in regions of orographic influence. Journal of Hydrology* 57: 23- 48.]

Table 1. Elevation-precipitation effects in the Green Lakes Valley.

Interval	Number of gauges in the correlation	Product moment correlation coefficient		Individual storm date	Number of gauges in the correlation
June-August	33	-0.19			
June	34	0.27		11 June	34
July	33	-0.21		19 July	33
August	30	-0.04		4 August	34
September	15	0.35		1 Sept.	30

Temperature Regulation of Soil Respiration in an Alpine Tundra Ecosystem

Cory C. Cleveland and Elisabeth A. Holland, Jason C. Neff

Poster Abstract. Climate is an important force regulating microbial activity and decomposition in soils. Significant increases in temperature, like those which are predicted in many global warming scenarios, may increase CO₂ release (respiration) from soils. Models of CO₂ exchange are sensitive to how temperature controls over soil respiration are represented. Because a large proportion of terrestrial carbon is stored in arctic and alpine soils, it is important to understand how temperature influences soil respiration fluxes from these soils. The purpose of this study was to measure the effect of temperature on soil respiration in an alpine tundra ecosystem. Surface soil samples from a range of plant communities at Niwot Ridge including wet meadow, moist meadow, dry meadow, and fell field communities were incubated at 5, 10, 15, 25, and 35°C, after amending soil moistures to field capacity. CO₂ evolution resulting from soil respiration was measured on day 1, and days 3 and 6 of the incubation. At all sites, CO₂ production increased to a maximum at 35°C and declined rapidly with time at the highest incubation temperatures. The pattern of response was remarkably similar to that found in similar incubations of tropical soils. In all cases, the pattern of response changed with time because substrate availability became more limited with time of incubation.

Effects of Gophers on Ecosystem Processes in Alpine Tundra

M. Roberto Cortinas, James C. Halfpenny, M. Iggy Litaor, Timothy R. Seastedt

Talk Abstract. Effects of gopher mounds and gopher activity on physical and chemical properties of alpine soils have been evaluated with a series of studies. Gophers alter both the texture and the chemistry of soils by their burrowing activities. Mounds affect litter decomposition rates directly, by burying litter, and indirectly, by affecting temperature and moisture properties of the soil. The combination of enhanced erosion and changes in the amounts of belowground plant carbon allocation results in large changes in the carbon storage potential of soils on moderate slopes. In essence, the gophers prevent the plant- soil system from maturing into a hypothetical Kobresia-like meadow. Results from summer, 1993 measurements on gopher impacts on soil temperatures, moisture and total soil carbon will be presented.

A Twenty-Five Year Study of Talus Movement, Colorado Front Range

Thomas C. Davinroy

Poster Abstract. By reoccupation of two study sites of talus particle motion in the Colorado Front Range, I have extended observations from a 3-yr to a 25-yr period. Measurements of downslope movement of talus in high-elevation (3600 m) alpine couloirs was initiated in 1967 and resampled in 1992. The study period was marked by several high-intensity storms, including a 100-yr precipitation event (52 mm in 8 hr). I have analyzed downslope movement according to particle size, particle shape, initial position, slope, and fluvial regime as a function of precipitation quantity, precipitation intensity, and climatic fluctuation. Lichenometric dating confirms the episodic nature of talus deposition within the Holocene. Mean displacement over the 25-yr period was 14.7 m ($0.59 \text{ m} \cdot \text{yr}^{-1}$), 5 times the rate measured in 1967. Regression analysis indicated that the transport distance was not correlated with particle size and inversely correlated with a particle shape index defined as the ratio of the particle dimensions. Displacement distance increased as particle shape approximated a sphere. Dispersion patterns and travel distance were found to be highly variable within and between sections of talus deposits.

Clonal Diversity and Phenotypic Plasticity in Three Alpine Populations of *Polygonum viviparum* (Polygonaceae)

Pamela K. Diggle, Steven S. Lower, and Kristine S. Stitt

Talk Abstract. Preformation, the development of structures such as leaves and flowers one or more seasons before they function, has been documented for the rhizomatous alpine perennial *Polygonum viviparum*. Leaves and inflorescences are initiated two to three years before they emerge above ground and initiation and development of flowers occurs one year before emergence. This developmental pattern is expected to constrain phenotypic responses to environmental variation (phenotypic plasticity). *P. viviparum* is not amenable to the usual experimental methods of measuring phenotypic plasticity. An alternative approach to the study of phenotypic plasticity (and developmental response to environmental heterogeneity) is provided by the unique reproductive system of *P. viviparum*. *P. viviparum* reproduces asexually via propagules that can be dispersed at great distances from the parent. One consequence of this mode of reproduction is that there are genetically identical but physiologically independent individuals replicated across the various communities on Niwot Ridge. We have used starch-gel electrophoresis to identify twenty-three clones (genotypes) in three communities on Niwot Ridge. Analysis of variance shows significant phenotypic variation of clones across communities (**Figures 3-4**) suggesting that individual genotypes of *P. viviparum* are capable of developmental response to environmental variation.

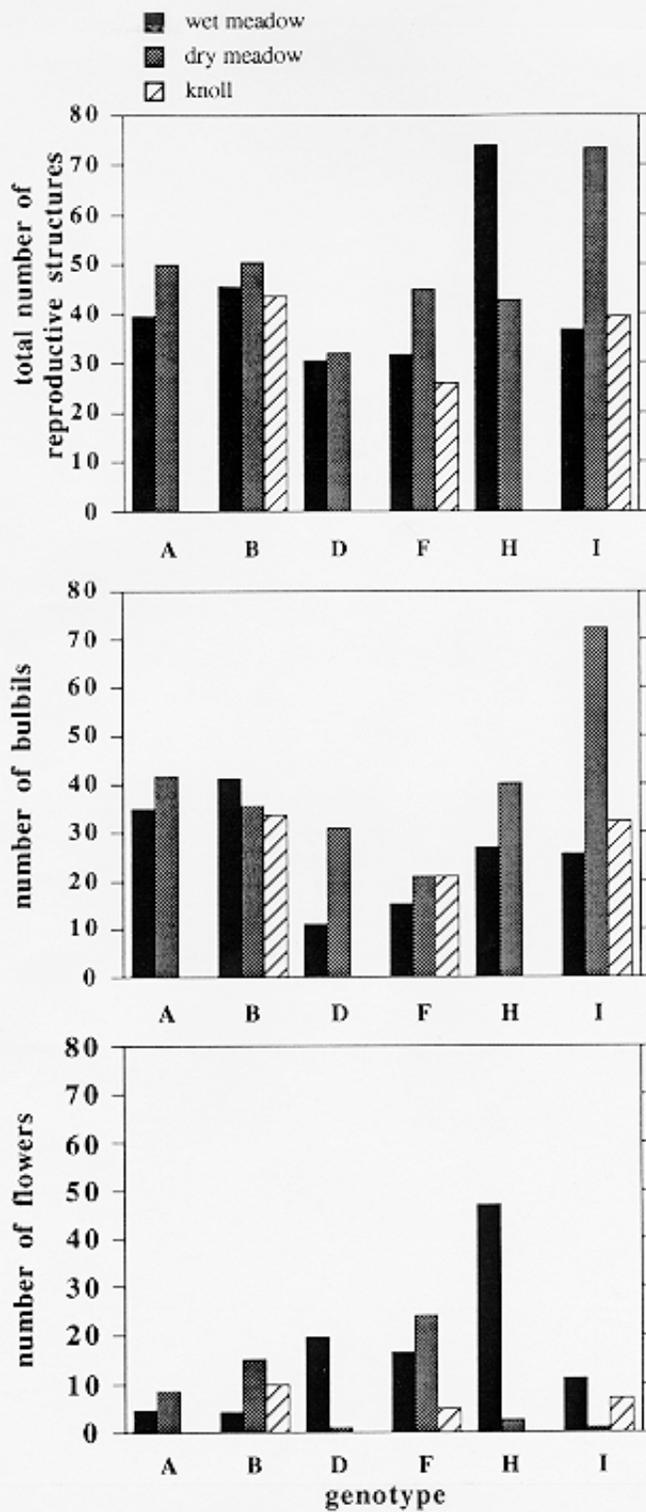


Figure 1 (for Diggle, Lower, and Stitt). Average phenotype for individuals of the same multi-locus genotype growing in three different communities on Niwot Ridge.

Figure 3. Average phenotype for individuals of the same multi-locus genotype growing in three different communities on Niwot Ridge.

GENOTYPE A

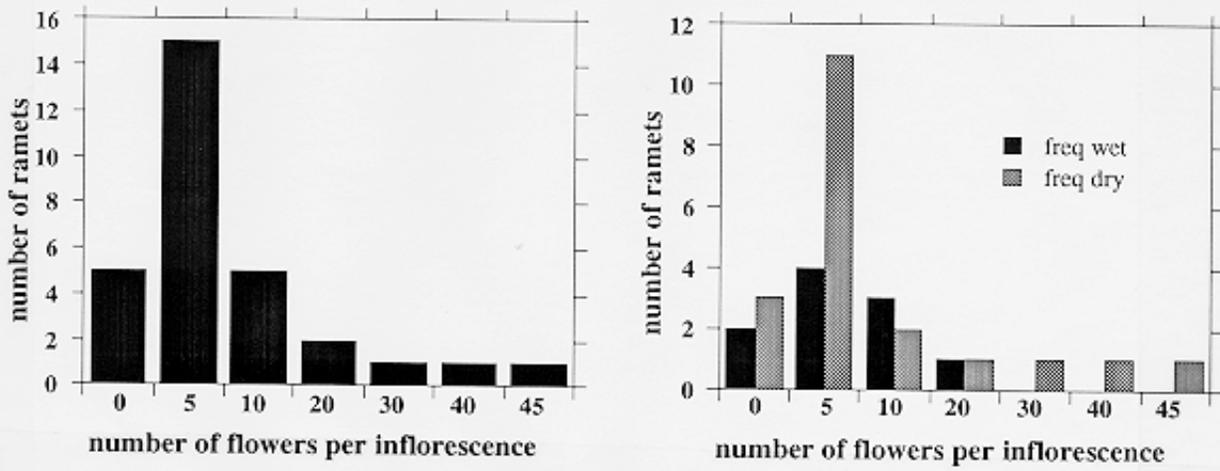


Figure 2. Phenotypic variation among individuals of genotype A. Left figure is total frequency of individuals with each genotype and right figure is frequency of individuals with each phenotype in two environments.

Figure 4. Phenotypic variation among individuals of genotype A. Left figure is total frequency of individuals with each genotype and right figure is frequency of individuals with each phenotype in two environments.

Biotic Response to Changing Alpine Environments During the Holocene

Scott A. Elias and Susan K. Short

Poster Abstract. As part of our research on biotic response to changing alpine environments, researchers in the paleoecology group of the Niwot LTER project have studied a transect of ten Holocene-age sites in the Colorado Front Range (**Figure 5**). Pollen, fossil insects, and plant macrofossils have been investigated. At the end of the last glaciation, the alpine tundra zone extended 500 m downslope from its modern limit. Early Holocene treeline reached its modern elevation by about 9500 yr BP (**Figure 6**). During the Holocene, the study region has experienced a series of climatic fluctuations, with fossil data indicative of warmer than present conditions between 9500 and 7000 yr BP, and colder than present conditions between 4500 and 3000 yr BP and again in the last 1000 years. The insect response has essentially been in phase with vegetational changes.

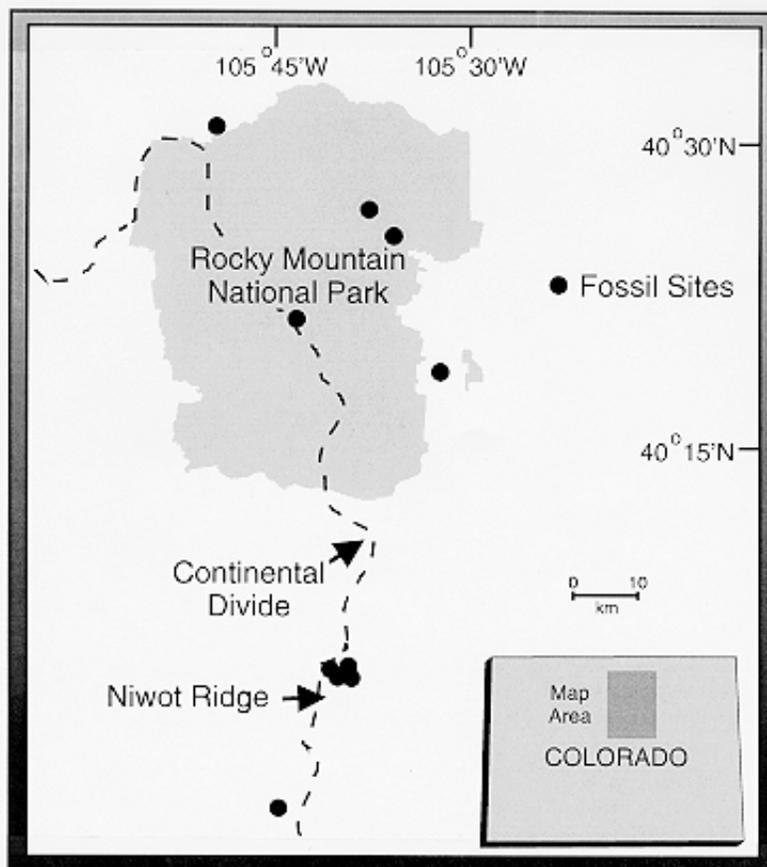


Figure 1. Location of study sites.

Figure 5. Location of study site.

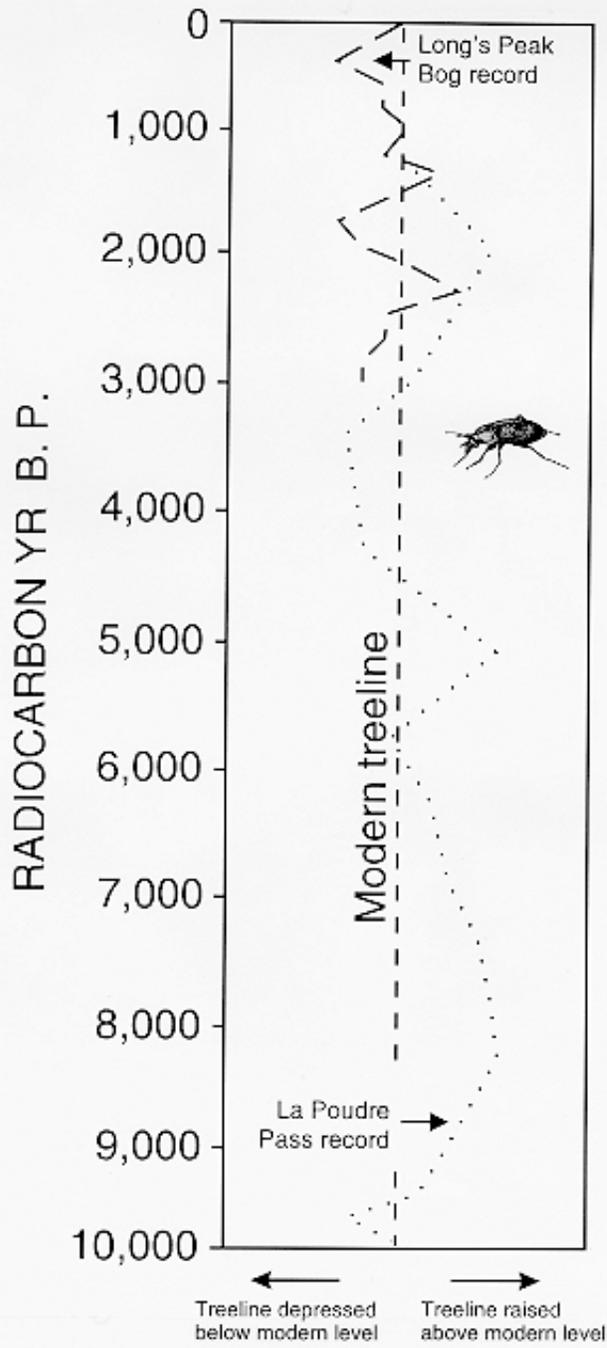


Figure 2 (for Elias and Short). Changes in Holocene treeline elevation, Colorado Front Range, based on fossil insect data.

Figure 6. Changes in Holocene treeline elevation, Colorado Front Range, based on fossil insect data.

Microbial Response to Increased Soil Moisture in Colorado Alpine Tundra Soils

Melany C. Fisk and Steven K. Schmidt

Poster Abstract. The response of microbial community composition and nitrogen mineralization to increased soil moisture was investigated in lab incubations and field manipulations of alpine tundra soil. Microbial respiration, net nitrogen mineralization, and total and active bacterial numbers were higher in soils incubated at 85% than at 30% gravimetric soil moisture, while fungal hyphal lengths showed no difference between soil moisture levels. In incubated, watered treatments higher bacterial numbers corresponded to lower net N mineralization per unit C mineralized, suggesting that higher N immobilization occurred as a result of stimulated bacterial activity and growth. Similarly in field experiments microbial biomass N was high in watered compared to unwatered soils, whereas net N mineralization did not increase in response to watering. While fungal biomass showed little response to higher soil moisture, short-term bacterial immobilization of N appears to be an important component of N dynamics, especially in response to wetting and drying cycles in alpine tundra soil.

A Model of Methane Production in Soils

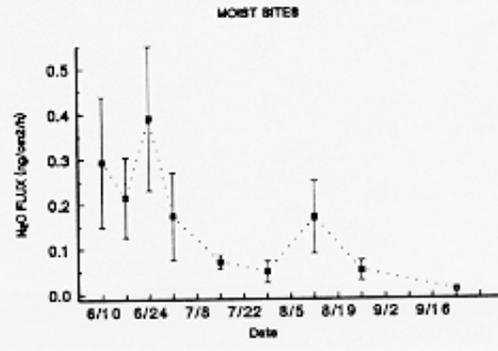
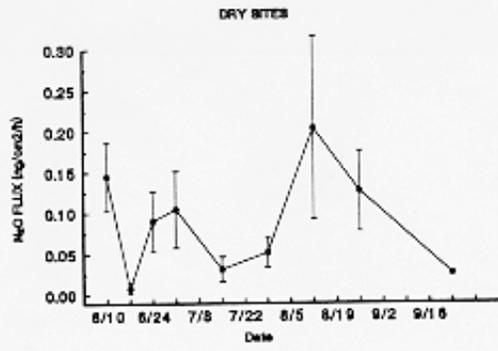
Elisabeth A. Holland

Poster Abstract. We have developed a simple model of methane production for flooded soils. Labile substrate supply is simulated as a proportion of the carbon decomposed and is controlled by temperature, moisture, and litter quality (lignin:N). The proportion of labile substrate converted to methane (rather than CO₂) is controlled temperature, pH, substrate supply and quality. The model parameterizations are based on a series of laboratory experiments which examined the CH₄ response to ethanol, litter, and root amendments, temperature and pH manipulations in anaerobic slurries. Preliminary comparisons demonstrate that the model is able to effectively simulate CH₄ production for a range of environmental conditions and that methane production is sensitive to both the amount and quality of incoming carbon as well as pH.

Dynamics of Phosphorus and Nitrogen Uptake as Related to Development of Fungal Endophytes in *Ranunculus adoneus*

Renee B. Mullen and Steven K. Schmidt

Poster Abstract. Phosphorus and nitrogen levels, phenology of roots and shoots, and development of vesicular arbuscular mycorrhizal (VAM) fungi and other endophytes were monitored for two years in natural populations of the perennial alpine herb, *Ranunculus adoneus*. The purpose of this study was to understand how endophyte development relates to phosphorus and nitrogen uptake in *R. adoneus*. This was accomplished by quantification of structures of VAM fungi and other root endophytes during maximum nutrient accumulation. Arbuscules were only present for a few weeks during the growing season of *R. adoneus* and their presence corresponded with increased phosphorus accumulation in both the roots and shoots of *R. adoneus*. Nitrogen accumulation appeared to be related to relatively high levels of a dark septate fungus. In addition, phosphorus accumulation and peaks in mycorrhizal development occurred well after plant reproduction and most plant growth had occurred. The late season accumulation of phosphorus by mycorrhizal roots of *R. adoneus* could be stored for use during early season growth and flowering the following spring. In this way *R. adoneus* can flower before soils thaw and root or mycorrhizal nutrient uptake can occur. (see **Figure 7**)



Fluxes of Nitrous Oxide and Methane from Nitrogen Amended Soils in the Colorado Alpine

Jason C. Neff, William D. Bowman, Elisabeth A. Holland

Poster Abstract. Fluxes of nitrous oxide and methane between soils and the atmosphere strongly contribute to the global atmospheric balance of radiatively important trace gases. In addition, the exchange of nitrous oxide and methane between tundra soils and the atmosphere may represent an important step in the cycling of nitrogen and carbon through alpine ecosystems. The microbial processes governing nitrous oxide and methane fluxes are sensitive to the availability of nitrogen in soils. This sensitivity, however, has not been quantified in alpine tundra soils. We examined the influence of nitrogen additions on the fluxes of nitrous oxide and methane from wet and dry meadow communities on Niwot Ridge. Urea nitrogen was added to experimental plots in June of 1990 and July of 1991. Using flux chambers installed in the tundra from June to August of 1992, we measured emissions from five nitrogen-amended plots and five control plots in each community. Our results indicate that the addition of nitrogen to the dry meadow community resulted in a 52% reduction in methane uptake (**Figure 8**) and a 22-fold increase in nitrous oxide emissions (**Figure 9**). Nitrous oxide emissions in the wet meadow community increased by a factor of 45 (**Figure 8**) while methane fluxes were not significantly changed.

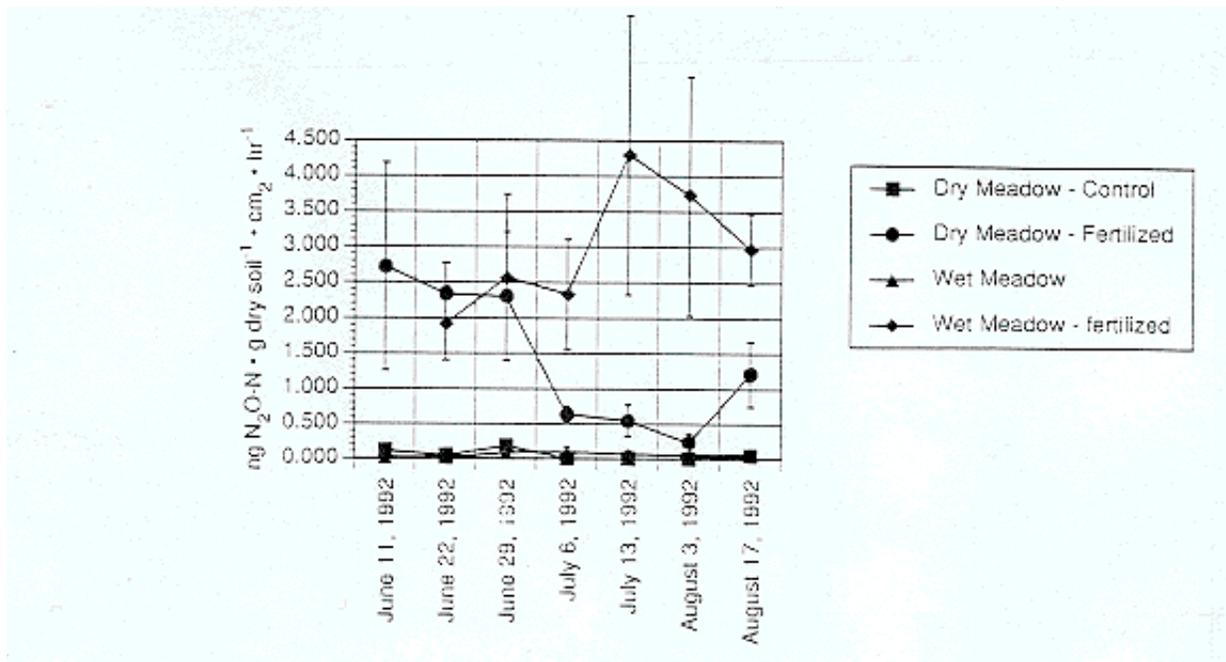


Figure 8. Nitrous oxide fluxes from nitrogen amended and control plots on Niwot Ridge, Colorado.

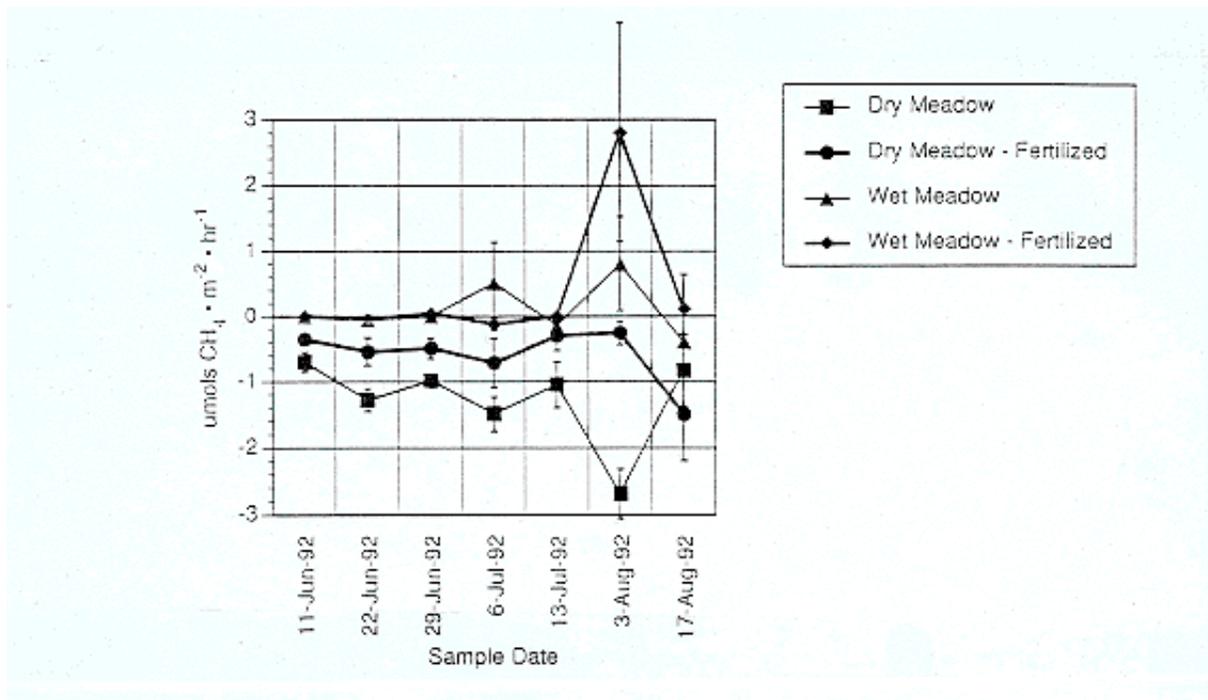
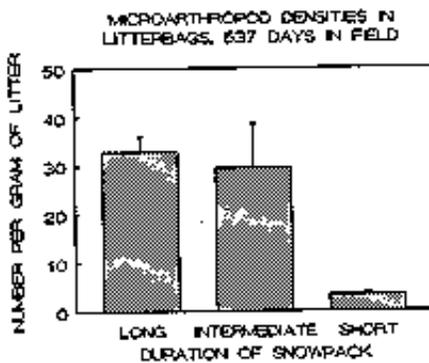
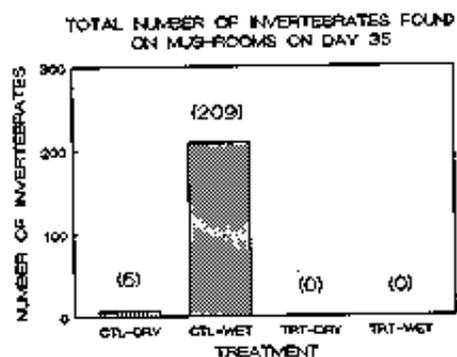
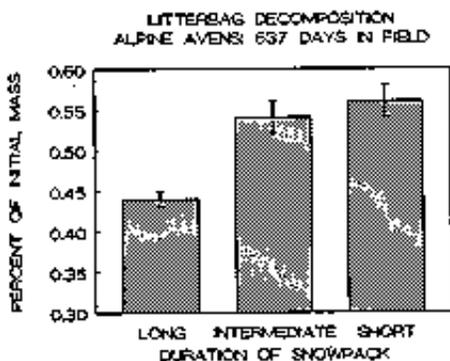
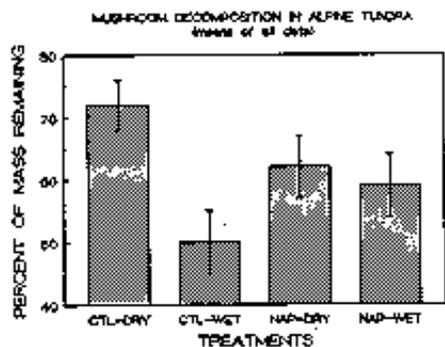


Figure 9. Methane fluxes from nitrogen amended and control plots on Niwot Ridge.

Microarthropod Densities and Impacts on Decomposition Across the Alpine Landscape

Heather A. O'Lear, Timothy R. Seastedt

Poster Abstract. Densities of microarthropods were measured in the top 5 cm of litter and soil in xeric, mesic, and wet alpine tundra habitats. Previous studies have underestimated densities due, we believe, to inefficient extraction techniques. High-gradient extraction produced densities averaging about 100,000 individuals per m²; no differences were observed among habitats. In contrast, microarthropod densities in litter contained in litter bags exhibited strong landscape patterns that were correlated with litter decomposition rates. A basidiocarp fungus decomposition experiment conducted in summer, 1993, in mesic and dry sites used naphthalene to exclude microarthropods from this detritus. Results indicated that decay was most rapid in mesic habitats. Arthropod fauna had a significant effect on decay rates in mesic habitats, but were unimportant (and largely absent) in decaying mushrooms in dry habitats. (See **Figure 10**)



Temporal and Spatial Variation in N₂O and CH₄ Fluxes Across an Alpine Landscape

Steven K. Schmidt, Lesley K. Smith, Melany C. Fisk, Jason Jaeger, Paul D. Brooks, Gregory M. Colores, and Ann E. West, Elisabeth A. Holland, William D. Bowman

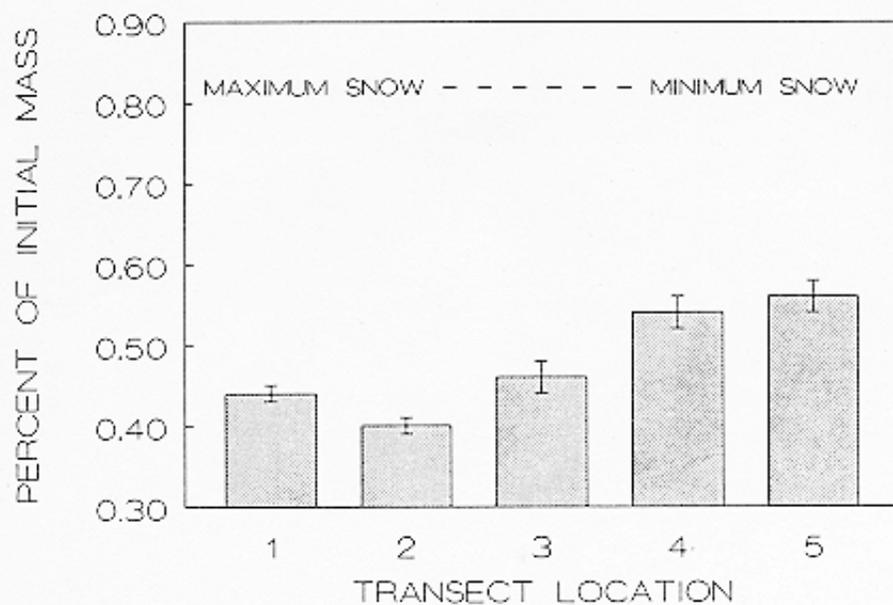
Talk Abstract. Fluxes of N₂O and CH₄ were measured in three alpine tundra plant communities (3 sites per community) on Niwot Ridge. Measurements were taken weekly to bi-weekly from before snowmelt to well after plant senescence in 1992 and 1993. In addition, soil moisture, temperature and inorganic N levels were measured at each site on all sampling dates. Nitrogen mineralization, nitrification, microbial biomass nitrogen and plant assimilation of N were also measured periodically throughout the growing season at each site. N₂O production was highest in May and June in wet and moist meadow sites and tapered off to almost zero for July, August and September. In dry meadow communities, N₂O production showed a peak early in the season but also showed peaks of production in response to late season rainfall events. Moist and dry meadow sites were sinks for CH₄ for all but the earliest sampling dates in May of 1993. Wet meadow sites were always a source of CH₄. Overall, soil moisture was the most important environmental variable controlling N₂O and CH₄ fluxes from alpine tundra sites in 1992. Because moist and dry meadows are the dominant community types in the Colorado alpine, it appears that alpine tundra acts as a net source of N₂O and a net sink for CH₄.

Controls of Decomposition in Alpine Tundra

Timothy R. Seastedt and Marilyn D. Walker

Poster Abstract. Litterbag studies were used to evaluate the importance of landscape position and substrate quality on decomposition processes. Sites of intermediate snowdepth exhibit the highest decomposition rates for surface litter during both the first and second years of decay. Such sites are neither strongly temperature limited (snowfield sites) or moisture limited (e.g., sites blown free of ca. 80% of annual precipitation). Initial nitrogen content of litter was positively correlated with decay rates for the first year of decomposition; initial lignin content was inversely correlated with decay rates. **(Figure 11)**

LITTERBAG DECOMPOSITION
ALPINE AVENS: 637 DAYS IN FIELD



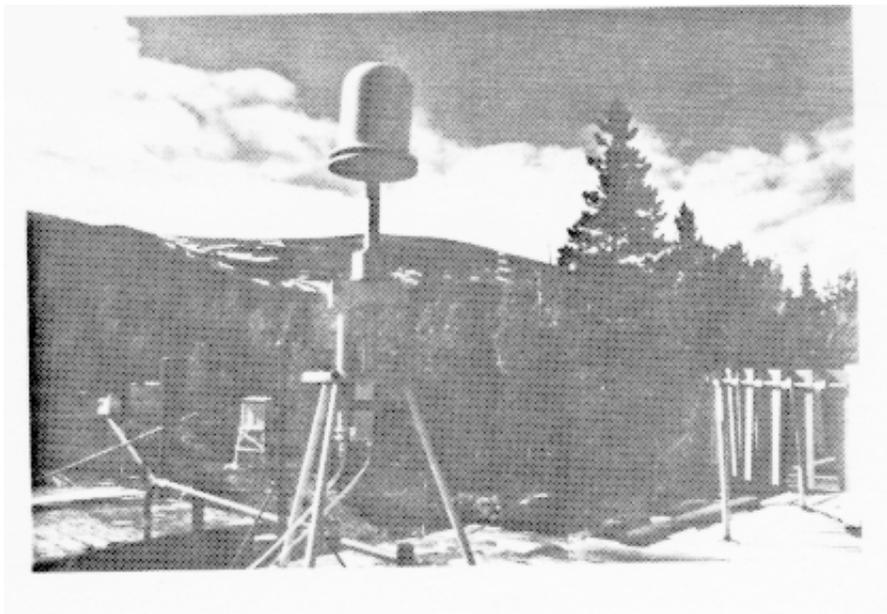
Atmospheric Loading of Nitrogen to Alpine Tundra at the Saddle Site

Herman Sievering, Timothy J. Bardsley, Rom S. Leidner, Lori Marquez, Christine Seibold

Talk Abstract. Atmospheric gaseous nitric acid (HNO₃) plus particulate matter nitrate (NO₃) and ammonium (NH₄) concentrations have been determined for the Saddle site on an approximately biweekly basis during the winter 1992-93 and on a weekly to twice-weekly basis since April 1993. These N species are the dominant contributors to atmospheric N loading at the Saddle site alpine tundra. Results include:

- * establishing a very low minimum detectable NH₄ air concentration measurement capability; and
- * obtaining sufficient ambient air concentration data to assess atmospheric N loading during 1993 snowmelt conditions.

A comparison of these 1992-93 data with ambient air concentrations observed at the C1 site (**Figure 12**) in 1978-81 and an update on 1990 N loading to the Saddle site tundra will be presented.



The Effects of Neighbor and Nitrogen Availability on Biomass and Nitrogen Accumulation and Allocation in Two Alpine Graminoids, *Deschampsia caespitosa* and *Kobresia myosuroides*

Theresa A. Theodose and William D. Bowman

Poster Abstract. Two dominant alpine tundra graminoids, *Kobresia myosuroides* from a low resource environment and *Deschampsia caespitosa* from a more resource rich environment were subjected to high and low N treatments in the absence and presence of inter- and intraspecific neighbors to investigate how each species responds to N and if that response is influenced by neighbor. *Deschampsia* accumulated significantly more biomass and N than *Kobresia*, regardless of N or neighbor treatment. *Deschampsia* responded significantly to N availability with increases in root and shoot biomass and nitrogen concentration and decreases in biomass an N root: shoot ratios in the high N treatment. Neighbor had no effect on *Deschampsia* biomass accumulation, but presence of a neighbor resulted in increased biomass and N allocated to shoots relative to roots. *Kobresia* biomass accumulation and N and biomass allocation did not respond significantly to N availability, but root nitrogen concentration increased in the high N treatment. When grown with *Deschampsia*, *Kobresia* increased N and biomass allocation to shoots relative to roots. Under high N, this response to *Deschampsia* resulted in increased tillering, biomass per tiller, total shoot biomass and possibly total plant biomass in *Kobresia*. Thus *Deschampsia*, a dominant of resource rich moist meadows accumulated more biomass and N and was more plastic in its response to N availability than *Kobresia*. Although *Kobresia*, a dominant of resource poor dry meadows had the more conservative growth response, allocation patterns shifted so that growth was not inhibited by the presence of *Deschampsia*, even under high N conditions.

The International Tundra Experiment (ITEX)

Marilyn D. Walker

Talk Abstract. The International Tundra Experiment is a consortium of research sites seeking to understand the response of tundra plant populations to changes in growing season temperatures through a simple temperature manipulation and transplant experiment. The research goal is to examine the phenologic and reproductive responses of a set of species to experimentally-induced warming at a network of sites. The ITEX design is hierarchical, with sites participating at whatever level they are able. At the minimum, participation in ITEX requires climate monitoring (using the LTER MSR standards), a temperature manipulation using one of three possible designs, and monitoring phenologic and reproductive variables for at least one designated ITEX species or two other species. The temperature manipulation consists of conical or hexagonal open-top chambers of solar fiberglass, which have been shown to increase the air temperature at the surface approximately 3°C. An ITEX program is being developed on Niwot Ridge as a logical outgrowth of the long-term phenology studies there. We are using a factorial design based around the snowfence experiment. Twenty cones are placed behind the snowfence, distributed at 10, 25, 45, and 75 m from the fence; each cone is paired with an adjacent plot. This results in the following treatments: increased winter snow, increased summer temperature, increased snow and increased temperature, and control. Key phenologic, growth, and reproductive traits are being followed on marked individuals of *Acomastylis rossii* and *Bistorta bistortoides*, and complete species composition is being monitored. Niwot Ridge is presently the only mid-latitude alpine site, although a site is now being developed in the Austrian Alps. [ITEX was initiated and organized at a workshop held at the Kellogg Biological Station in December 1990, attended by representatives of the arctic rim nations (Canada, Denmark, Finland, Iceland, Norway, Sweden, USA, and USSR) and Great Britain. ITEX is coordinated by a Directorate, with administrative support from various MAB programs. For further information on the ITEX network, contact: Per Molgaard, ITEX Secretary, Danish Polar Center, Høusegade 3, DK-1128 Copenhagen, Denmark.]

A 100-Year Experiment to Examine Long-Term Ecological Effects of Altered Snow Regimes to Alpine Ecosystems

Skip A. Walker, William B. Krantz and Brad E. Lewis, Erik T. Price, Ronald D. Tabler

Talk Abstract. The Niwot Ridge Long-Term Ecological Research (LTER) has begun a snow-fence experiment to examine the consequences of altered snowpack regimes in alpine ecosystems. This poster describes the principal questions that are being addressed, the design of the experiment, an update on the status of the fence construction and experimental plot layout, and the results of the first winter's snow-depth (**Figure 1** and **Figure 2**) and ground-temperature observations (**Figure 3**). Snow depths are reported for a 350 x 500-m grid surrounding the experimental site (**Figure 1**) and for more intensive measurements in the 60 x 125-m snow-fence experiment study area (**Figure 2**). The period November 1992 to April 1993 had 183% of average snowfall at D-1, and April was the wettest month on record. Patterns of snow distribution reported here may be representative of conditions that could be expected with increased snow fall (Table 2).

Table 2. Winter 1992-93 temperatures and precipitation and comparison with 1951-85 means (Greenland 1991) at the D-1 station, Niwot Ridge, Colorado. Mean values for 1951-1985 are in parentheses.

Time Interval	Precipitaion (mm)	Mean temperature (degrees C)
November	152 (80)	-11.6 (-8.9)
December	150 (90)	-12.3 (-11.8)
January	98 (102)	-11.4 (-13.2)
February	235 (80)	-12.3 (-12.8)
March	155 (128)	-9.2 (-11.2)
April	271 (100)	-7.3 (-7.0)
November-April	1061 (580)	

1. Greenland, D 1989. The climate of Niwot Ridge, Front Range, Colorado, U.S.A. Arctic and Alpine Research 21: 380-391.
2. The D-1 station is 2.3 km west of the Saddle and about 100m higher (elevation 3794 m)
3. April 1993 was the wettest month on record at D-1.
4. November to April precipitation was 183% of the 1951-85 average for the same period.

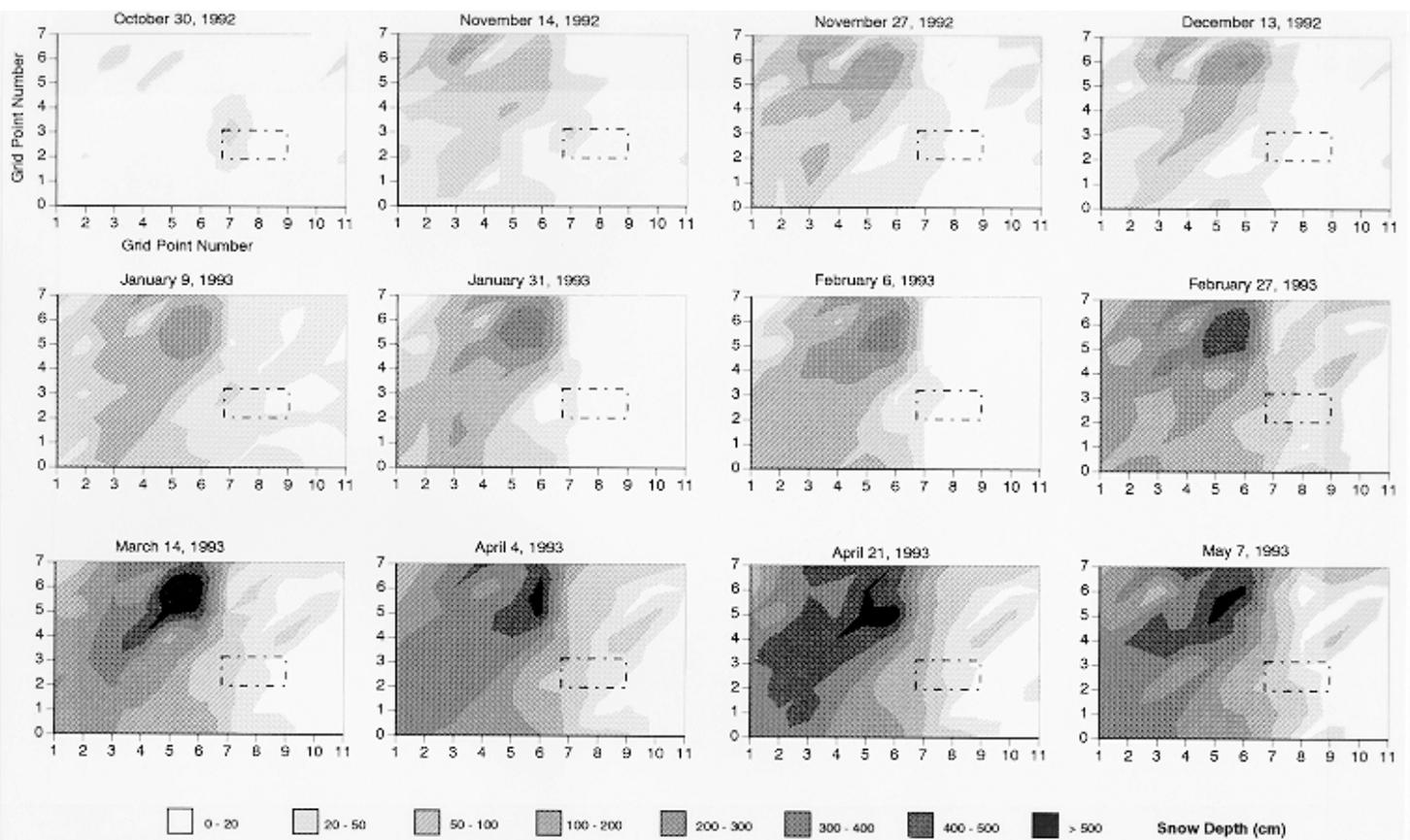


Figure 1. (for Walker, Krantz, Lewis, Price, and Tabler). Snow-depth baseline study in the Saddle grid (350 x 500 m). A grid of 88 snow stakes were used to monitor snow in the Saddle grid. Snow accumulation in the early winter (October 30 to November 27) occurred in willow areas (central portion of grid) and in depressions associated with stone-banked terraces (upper left portion of the grid). Later in the season, the macrotopography of the Niwot Saddle determined drift patterns. Winds are predominantly from the west (left), and snow accumulates on east-facing aspects and in a large depression in the upper central portion of the grid. The east side of the grid is predominantly west-facing and has shallow snow or is blown free of snow throughout the winter. Strong winds on Niwot Ridge cause periods of snow deflation over much of the grid with deposition in the deep snow-accumulation areas. Wind deflation of the snowpack over most of the grid is evident on December 13, January 31, February 6, March 14, and May 7.

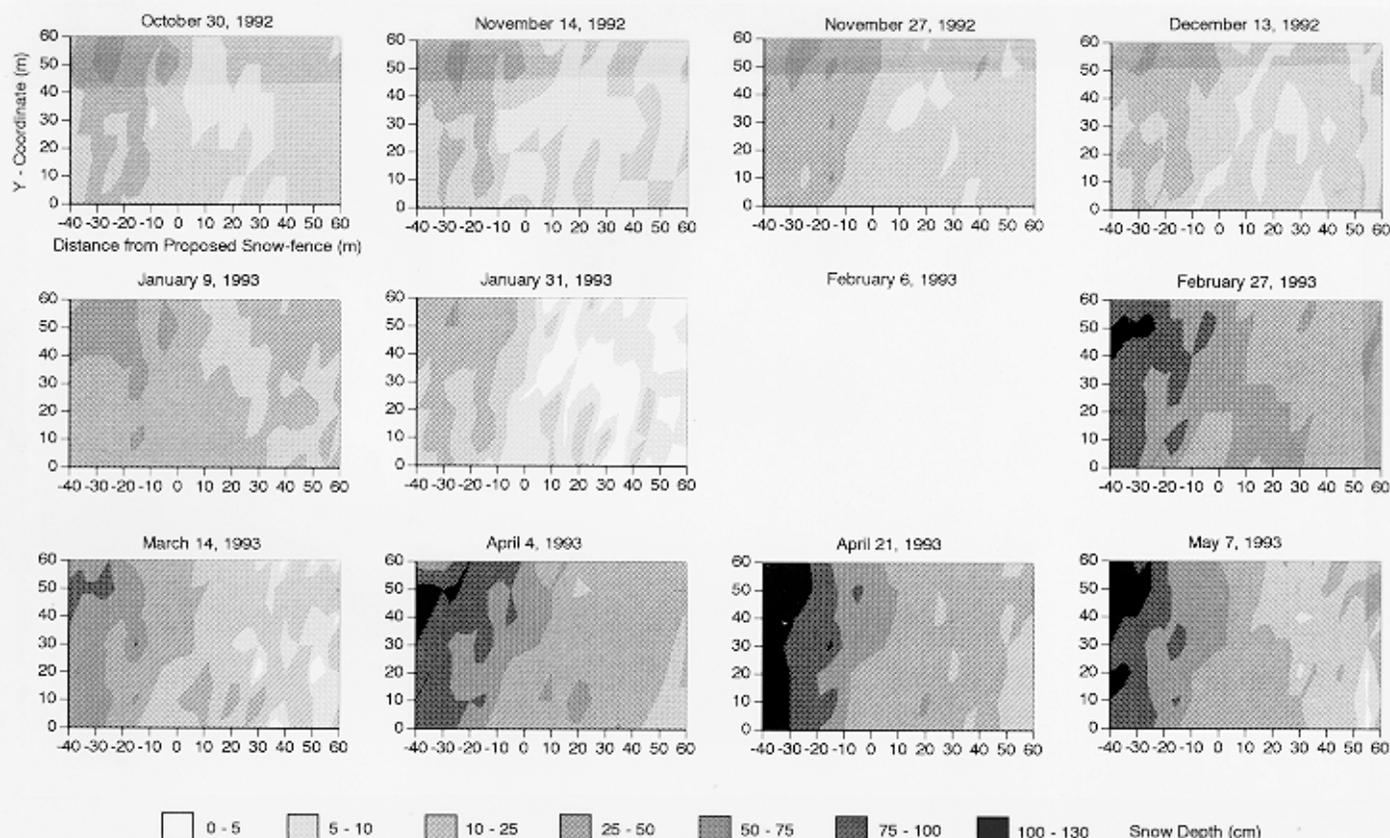


Figure 2. (for Walker, Krantz, Lewis, Price, and Tabler). Snow-depth baseline study in the snow-fence experimental area (60 x 100 m) from October 30, 1992 to May 7, 1993. A grid of 140 snow stakes were used to monitor winter snow depths in the snow-fence experimental area. The deeper snow occurred in the *Acomastylis* and *Salix* communities (-40 to 5 m along the transect), and generally shallow snow occurred in the *Kobresia* meadow (5 to 60 m). Dates of deeper snow (November 27, January 9, February 27, and April 4) alternated with deflation of the snowpack by wind in the intervening periods. During the early winter (October 30 to January 31) the deepest snow was found in the *Salix* community where willows trapped the snow. Later in the winter (April 21), a large snowdrift associated with the west side of the Saddle overwhelmed the western portion of the grid.

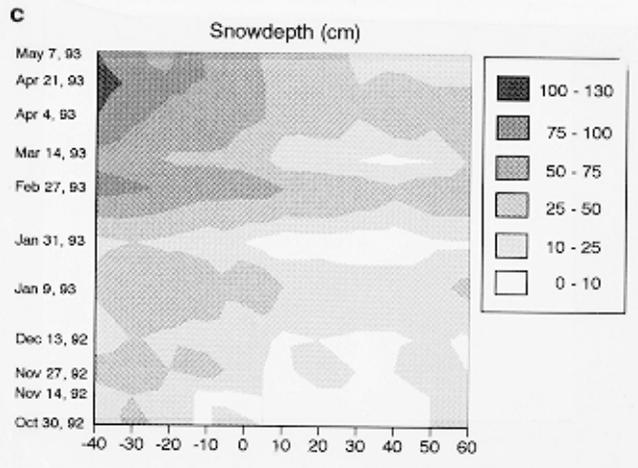
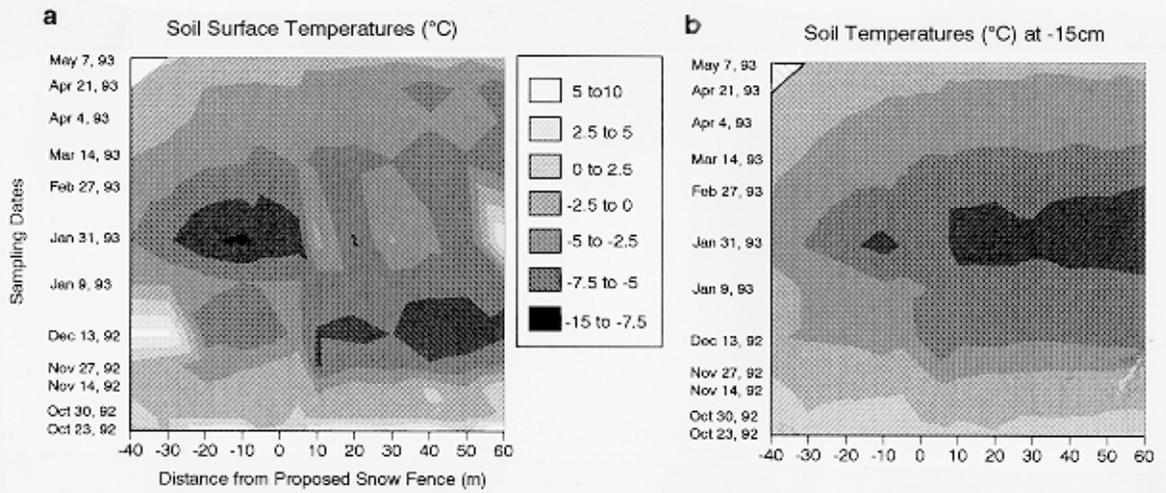


Figure 3. (for Walker, Krantz, Lewis, Price, and Tabler). Ground temperature baseline studies. (a) Ground-surface temperatures along a transect through the center of the snow-fence grid from October 30, 1992 to May 7, 1993. (b) Temperatures at 15-cm depth. In the *Kobresia* meadow (5 to 60 m) at the 15-cm depth, the temperatures gradually cooled to about -11°C on January 31. These temperatures corresponded to the coldest air temperatures and a period of shallow snow cover. Temperatures were generally 2° to 5°C warmer in the *Salix* and *Acomastylis* communities (5 to -40 m). (c) Snow cover along the transect for the same time period. Note the periodic pattern of deposition and wind deflation. Minimum ground temperatures occurred during the January 31 period when the snow cover was also low.

Extrapolating Primary Production Measurements Across a Heterogeneous Alpine Landscape

Carol A. Wessman, Elizabeth A. Nel and C. Ann Bateson, Marilyn D. Walker

Poster Abstract. Estimates of regional alpine primary production using satellite imagery permit monitoring of natural variation in biotic/abiotic controls and directional variation associated with long-term climate change. However, the heterogeneous alpine landscape presents a challenging test for commonly-used spectral vegetation indices (SVI); confounding influences from background and topographic variation are substantial. Field spectrometry is being used at Niwot Ridge to test whether local production measurements scale linearly for satellite-based estimates of regional production. In 1992, we collected biomass, cover information, and spectral measurements at each of the 88 Saddle grid-points. SVIs were strongly correlated with live biomass amounts except for outliers representing areas containing large fractions of soil or rock (**Figure 13**). Spectral mixture analysis, applied to separate the green vegetation endmember from background end members (soil, rock), is being investigated to determine if separation of the vegetation signal from the background will improve estimates.

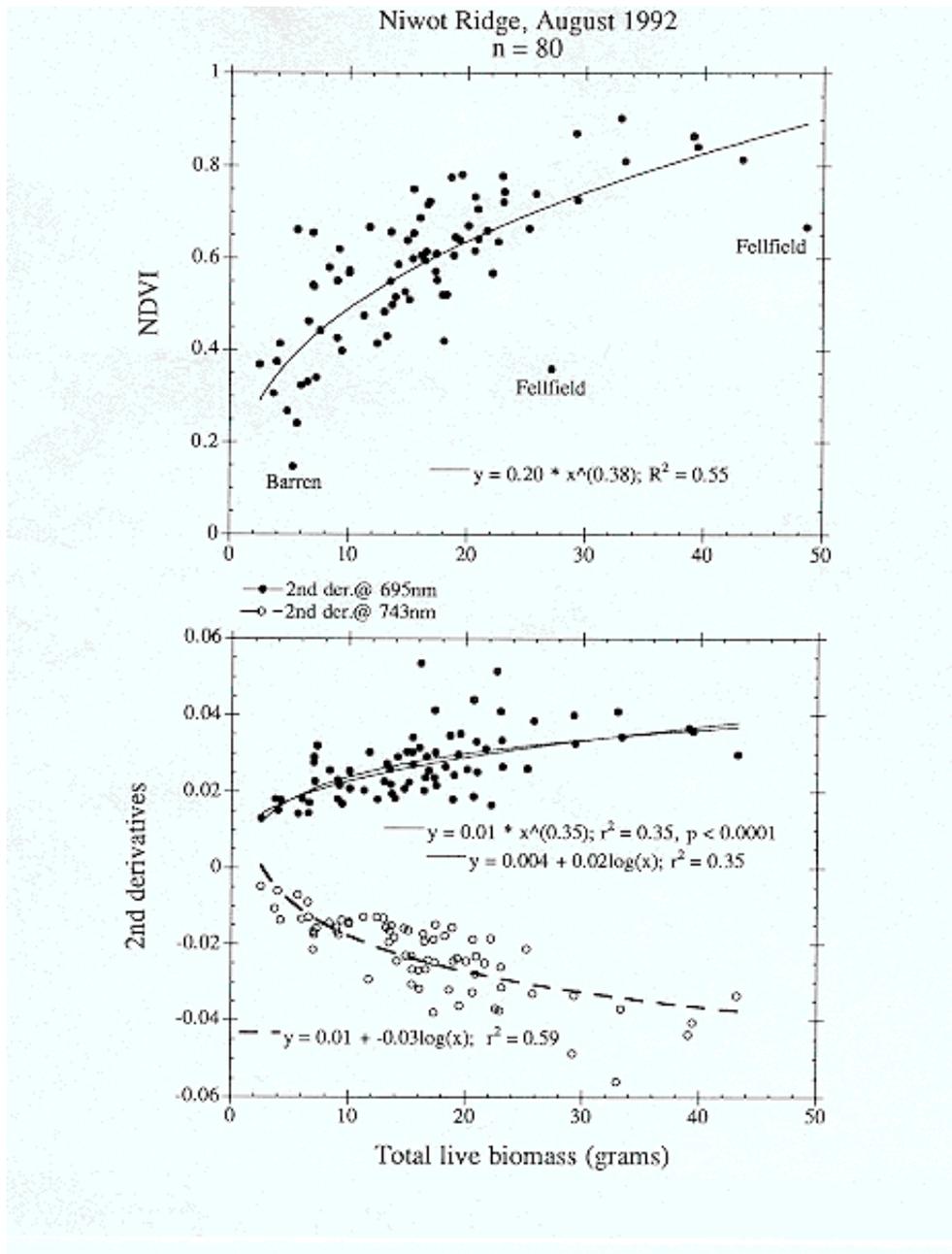


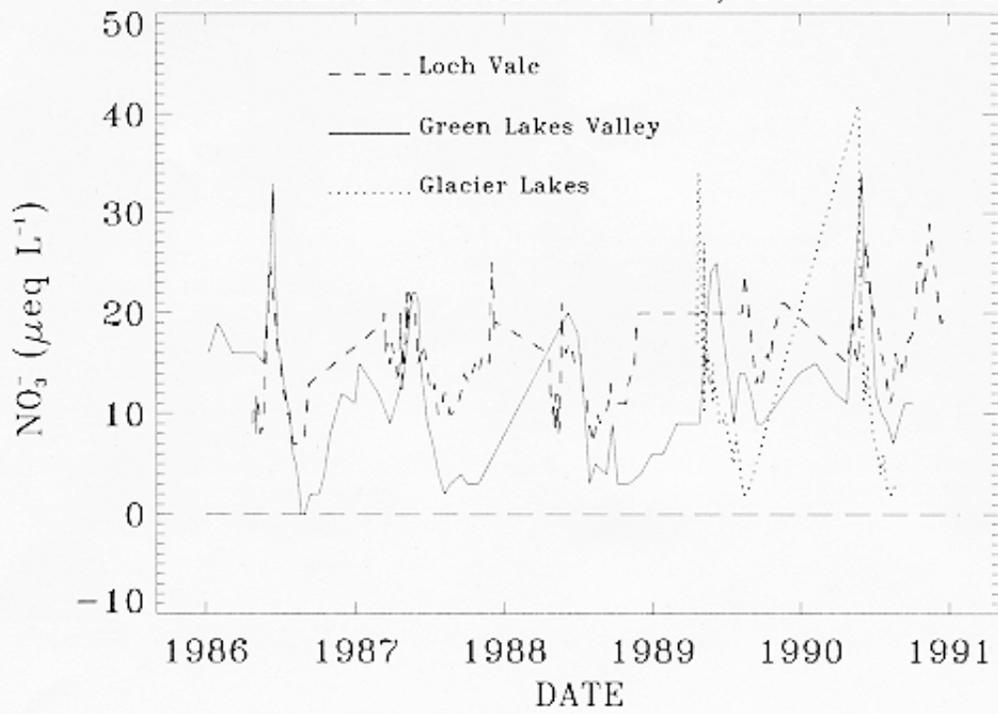
Figure 13. Power and logarithmic curve fits suggest strong correlations between live biomass amounts, NDVI (Normalized Difference Vegetation Index), and the second derivatives of the individual plot reflectance spectra.

Is Nitrogen Saturation Occurring in the Colorado Front Range?

Mark W. Williams and Nel Caine, Jill Baron, Richard Sommerfield

Talk and Poster Abstract. We seek to understand the role of nitrogen (N) in determining the quality of surface waters in headwater basins of the Colorado Front Range: Green Lakes Valley in the Indian Peaks Wilderness Area, Loch Vale Watershed in Rocky Mountain National Park, and the Glacier Lakes basin in southern Wyoming. The Colorado Front Range has the highest levels of N deposition collected at all NADP sites in the intermountain region. Deposition of NO₃⁻ at Niwot Ridge in the Green Lakes Valley measured 17.96 kg ha⁻¹ in 1990 with a 5-year average from 1986 through 1990 of 11.9 kg ha⁻¹ yr⁻¹. Over the same time period, NH₄⁺ deposition has increased 4-fold in the Green Lakes Valley and Glacier Lakes with a similar but smaller increase at Loch Vale. Maximum concentration of NO₃⁻ in surface waters of the three test basins occurs during spring snowmelt (**Figure 14**). The peak annual concentrations for NO₃⁻ of 25-35 meq L⁻¹ are 2-4 times the average concentrations of NO₃⁻ in the snowpack. Release of NO₃⁻ from the snowpack in the form of an ionic pulse appears to be the cause of these elevated values of NO₃⁻. The effect of increasing atmospheric deposition of N appears to be postponement of the seasonal switch from physical to nutrient limitation of biota during the breaking of dormancy in the spring, resulting in the high values of NO₃⁻ in stream waters at this time. More interesting, leakage of N occurs during low-flow conditions in the summer months, when surrounding base flow is predominately from subsurface discharge. The annual minimum concentrations of NO₃⁻ in 1990 at all three basins of about 10 meq L⁻¹ was similar to the volume-weighted annual concentrations of NO₃⁻ in wet deposition, evidence for Stage 2 nitrogen saturation (**Figure 14**). This leakage of N into surface waters during the period of high N demand by the biota suggests that biological uptake of N was not able to utilize all N from atmospheric deposition, N began to percolate below the rooting zone into ground water, and that subsurface contributions to stream flow then caused the increase in NO₃⁻ concentrations during the low-flow period.

SOUTHERN ROCKY MTNS, 1986-1990

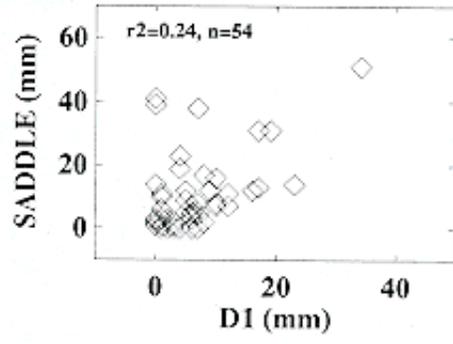


Oversampling of Snow by a Belfort Collector, Niwot Ridge, Colorado

Mark W. Williams, Mark Ridders, Chi Yang

Poster Abstract. Here we report the first evidence of oversampling of snowfall by a Belfort recording gage. Accurate measurements of precipitation quantity and quality are an important component of research activities at the NWT Ridge LTER site. These parameters are measured using a Belfort Universal Recording Gage to be consistent with the 200-site National Acid Deposition Program (NADP) measurements. Niwot Ridge is characterized by average wind speeds of 10-13 m s⁻¹ during the winter months, which may significantly affect the catch efficiency of the precipitation gage. We attempted to calibrate the existing Belfort recording gage using two methods: i) measurements from 5 snow boards were compared to the Belfort data on an event basis in 1993, and ii) historical meteorological data from 1988 to 1990 from sites C1 and D1 were compared to the Saddle for measured precipitation, wind speed, and daily solar radiation. Snowboard results suggests that the Belfort gage undercollects during some snow events. For example, on April 13, 1993, the mean snow water equivalence measured on the 5 snowboards was 64mm compared to 22 mm measured in the Belfort gage. The Belfort gage appears to collect blowing snow during days when no precipitation occurs, leading to an overestimate of the actual amount of precipitation. When precipitation amounts in April for the Saddle are regressed against those of D1 the correlation is not significant ($r^2=0.26$) (**Figure 15**). Removal of non-stormy days from the regression eliminated most of the points along the line $x=0$ in Figure 15 and provided a significant relationship ($r^2=0.75$) (**Figure 16**). Non-stormy days are defined as a day when solar radiation < 12 MJ d⁻¹. A similar analysis for the other months of the years from 1988 through 1990 indicates that the Belfort significantly oversamples solid precipitation but not rainfall. Modeling snowfall using these regression equations indicates that the Belfort gage may have oversampled annual precipitation at Niwot Ridge by 37% in 1988, 17% in 1989, and 31% in 1990. [Funding provided by the Undergraduate Research Opportunities Program, University of Colorado, Boulder, CO.]

ALL STORMS



CLEANED DATA

