Here is a brief summary of our ATLAS and NATEX activities.

ATLAS project

Participants: Jeff Welker, Jace Fahnestock, Bob Piper, Rena Baldwin, Mark Larson

Title: Collaborative research: Winter C flux in arctic ecosystems under changing climate: effects of soil carbon and active layer dynamics

Overall goal: Quantify the magnitude of winter CO2 flux across a range of arctic tundra ecosystems and plant communities. Collaborative projects by Schimel, Ping, Michaelson, and Romanovsky are documenting other winter biotic processes (e.g., microbial activity) and abiotic patterns (e.g., organic matter content, unfrozen water content).

Associated questions: 1) To what extent do winter CO2 fluxes vary within and between years? 2) How do winter CO2 fluxes differ among tundra communities?

Summary: We now have collected data three full winter seasons on this project (and two additional seasons before that on a separately funded project) enabling us to confidently describe the magnitude of winter CO2 fluxes in Arctic ecosystems and to begin establishing a long-term record of interannual variability in winter carbon losses. These examinations have let to the publication of three papers directly describing wintertime carbon losses (Fahnestock et al. 1998, 1999, Jones et al. 1999) and have contributed data to several other papers (Jones et al. 1998, Welker et al. 2000, Fahnestock et al. 2000). Two additional unpublished manuscripts (Schimel et al. 2001, Fahnestock et al. 2001) and a synthesis paper (Sturm et al., in preparation) include data from this project.

The long-term record we have been documenting in this project has shown some interesting patterns that would not have been discovered with short-term studies. For instance, the amount of carbon lost in some winters is substantially higher than others, and our studies indicate this to be largely a function of soil temperature, but directly related to the timing of fall snow accumulation. For instance, when snow comes early in the winter season, the soil is insulated from very cold temperatures, resulting in greater soil temperatures and greater free water availability during the winter. This leads to increased plant and microbial respiration throughout the winter compared to years when winter comes late and soils become very cold.

Our investigations of winter C dynamics over several years have also prompted us to initiate three additional studies that assess the importance of inter-seasonal connections in carbon and nutrient cycles. In the first study, we have shown that Arctic plants are capable of acquiring N while they are still under the snow, and that N availability in winter may be an important and often overlooked part of the annual N cycle of plants and microbes (these results are found in Bilbrough et al. 2001). These findings have led to a second study where we have examined N dynamics in all four seasons under ambient and elevated snow depths as part of our related NATEX grant (see below). These studies have shown that environmental conditions in the winter (e.g., warmer soils) have a significant impact on N availability in subsequent seasons (Bilbrough et al., unpublished manuscript). In the third study, initiated in the fall of 2000, we are examining the importance of the fall season on N uptake by plants and which forms of N (organic N, inorganic NH_4, inorganic NO_3) are most useable by plants in the fall. We believe that the short fall season in the Arctic may be the most important times for N capture by plants since water availability may be high at that time and competition with microbes low.

Over the past two years we have expanded our initial studies of carbon flux in the Kuparuk Basin (Fahnestock et al. 1998, 1999, Jones et al. 1999) to assess not only the representativeness of the Kuparuk Basin to other Alaskan tundra sites, but also to assess differences between Low and High Arctic communities and between coastal and continental communities. We have quantified winter C fluxes over two years in five different ecosystems in the Seward Peninsula at Council. These communities correspond to the five intensive sites that other ATLAS investigators (e.g., Chapin, Hinzman, Walker) have been examining at Council, and include tussock tundra, low and high shrub tundra, spruce forest, and several transition zones. We have also examined winter C dynamics in three High Arctic ecosystems at Alexandra Fiord on Ellesmere Island, Canada. This has been done in conjunction with Greg Henry and our NATEX project, which is examining summer CO_2 exchange patterns. Finally, we have expanded our measurements of winter C flux by making over-winter measurements in 15 sites from Fairbanks to Prudhoe Bay. This not only allow us to examine variation in flux over a large (500 mile) latitudinal gradient but also allows us to compare the relative contribution of different types of tundra ecosystems for example, spruce forest, tussock tundra, and wet sedge tundra to Arctic C budgets.

We are now in the final phase of our initial proposal. During this time our primary efforts will be to integrate our field results with those of our immediate collaborators on this project (Schimel, Ping and Michaelson, Romanovsky) to develop robust process-based models describing the controls on winter C fluxes. These models will be integrated into larger modeling efforts, such as TEM (McGuire) and the snow-shrub model (Sturm), and we will work with groups such as Chapin, Shaver and Oechel to incorporate our detailed winter research into their studies of summer and year-round CO_2 fluxes.

NATEX project

Participants: Jeff Welker, Jace Fahnestock, Carol Bilbrough, Paddy Sullivan, Kevin OЬea, Seth Arens, Ashley Burt, Tom Antonini, Mark McNeal

Title: Species responses to changes in climate across arctic gradients using the North American ITEX network (NATEX): influences on community and ecosystem processes

Overall goals: 1) Quantify growing season CO_2 exchange in high and low Arctic tundra communities. 2) Minirhizotron studies of roots at Toolik Lake.

Summary: We measured net ecosystem CO_2 exchange, respiration and photosynthesis throughout the 2000 growing season at Toolik Lake and Alexandra Fiord, Canada. Measurements were made approximately every two weeks in moist and dry tundra ecosystems at Toolik Lake and in wet, mesic and dry ecosystems at Alexandra Fiord. In addition, measurements were taken at all sites in plots that were warmed by open-topped chambers. At

Toolik Lake we also took measurements in the long-term experimental manipulation of increased wintertime snow accumulation.

In 2001, we increased our sampling at Alexandra Fiord and made measurements in wet, mesic and dry ecosystems on a weekly basis. Again, measurements included long-term (8-years) warming and ambient plots. The long-term warming experiment was initiated by Greg Henry. In conjunction with these gas exchange measurements, we measured snow depth (as necessary), depth of thaw, soil moisture, and air and soil temperatures.

Whole plant measurements of net CO2 exchange, respiration, and photosynthesis were made in mid- to late-July (peak season) at Alexandra Fiord on the dominant plant species at each of the major ecosystems (i.e., wet, mesic, and dry). These measurements, along with soil respiration measurements, will enable us to identify species-specific responses to warming and to ecosystem carbon exchange patterns.

Weekly plant samples were collected at Toolik Lake and Alexandra Fiord throughout the 2000 (and 2001 at Alex Fiord) growing season. These samples are currently being processed for C and N analyses which will be related back to our gas exchange measurements.

In 2001, we initiated a new component of our NATEX research at Toolik Lake to examine belowground root dynamics. We installed minirhizotron tubes in three treatments (ITEX open-topped chambers), fertilization (2 applications: June 5 and July 9, each at a rate of 15g N m-2) and increased winter snow deposition. We have initially installed 8 control tubes, 6 warmed tubes, 14 fertilized tubes and 8 tubes with increased winter snow deposition. Root images were collected every week from June 9 to August 15 at a vertical interval of 0.87cm. We will also make a trip to Toolik Lake in mid-October to look for evidence of fall/early winter root growth and activity.

The minirhizotron root images will be used to quantify root growth rate, decomposition rate, annual production (nutritive and massive), annual turnover (nutritive and massive), age class ratios, age class specific mineral nutrition, age class specific vertical distribution and relative abundance and standing belowground biomass.

To better correlate our minirhizotron images to above and belowground vegetation dynamics, we also collected soil cores and clipped aboveground vegetation every two weeks from June 11 to August 8. Soil cores were sorted into white, gray, brown, crown, fine and non-E. vaginatum roots. This data will be used to determine age-class specific root length density, age-class specific mineral nutrition, age-class specific and temporal variations in vertical distribution and relative abundance, age class ratios, standing below-ground biomass, annual production and above: below ground biomass ratio. Aboveground vegetation has been sorted into species, and live vs. dead material, to quantify species composition, species specific live: dead material ratio, species specific aboveground biomass, species specific mineral nutrition and above: below ground biomass. Aboveground growth measurements were taken about every week from June 5 to August 13 under all treatment regimes. Eriophorum vaginatum old shoots, new shoots and Betula nana stems were tagged and measured. These measurements yielded species-specific and age class specific growth rates and 2000 and 2001 net growth. Vegetation was sampled every week from June 6 to August 13 for species-specific mineral nutrition and temporal variation in mineral nutrition.

Publications resulting from these projects

Bilbrough CB, Welker JM and Bowman W. 2000. Early spring N uptake by snow-covered plants: A comparison of arctic and alpine plant function under snowpack. Arctic, Antarctic and Alpine Research 32:404-411.

Bilbrough CB, Schimel J and Welker JM. The effects of changing snow cover on year-round soil N dynamics in Arctic tundra. Unpublished manuscript.

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Fahnestock JT, Jones MH and Welker JM. 1999. Wintertime CO_2 efflux from arctic soils: Implications for annual carbon budgets. Global Biogeochemical Cycles 13: 775-779.

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Fahnestock JT, Welker JM, OЬea KW and Henry GHR. 2001. Annual carbon exchange in high and low arctic tundra: comparative responses to ambient and warmed conditions. Unpublished manuscript.

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Jones MH, Fahnestock JT and Welker JM. 1999. Early and later winter CO_2 efflux from arctic tundra in the Kuparuk River watershed, Alaska, U.S.A. Arctic, Antarctic, and Alpine Research 31: 187-190.

Jones MH, Fahnestock JT, Stahl PD and Welker JM. 2000. A note on summer CO_2 flux, soil organic matter, and microbial biomass from different high arctic ecosystem types in northwestern Greenland. Arctic, Antarctic, and Alpine Research 32: 104-106.

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Welker JM, Fahnestock JT and Jones MH. 2000. Annual CO2 flux in dry and moist arctic tundra: field responses to increases in summer temperatures and winter snow depth. Climatic Change 44: 139-150.

Welker JM, Fahnestock JT , OЬea KW and Henry GHR. 2001. Previously entombed ecosystems at the margins of shrinking arctic ice sheets and glaciers supply CO2 to the atmosphere. Unpublished manuscript.