

## DRAFT Final Report to NSF 1998-2000

### CLIMATE-DISTURBANCE INTERACTIONS IN THE ALASKAN BOREAL FOREST

#### Background

The Bonanza Creek (BNZ) LTER program was initiated in 1987 to study succession in the Alaskan boreal forest. The successional paradigm that emerged from this research is based on Jenny's (1941) state factor approach. The Central Hypothesis of the initial research program was that **"the *pattern* of succession is determined primarily by the initial soil physical and chemical environment of the site and by the life history traits of component species. The *rate* of successional change is determined by vegetation-caused changes in environment and ecosystem function."** Our research has largely supported this hypothesis (Yarie et al. 1998) but showed that successional pattern in the boreal forest is regionally variable (Mann and Plug 1999), reflecting stochastic variation in disturbance and recruitment. The boreal forest is the second most extensive terrestrial biome on earth (Whittaker 1975) and has many characteristics that set it apart from other ecosystems. It has a cold dry climate, making it potentially sensitive to climatic change. It has few dominant tree species, so changes in these tree species have large ecosystem impacts. It is relatively undisturbed by current human activities. Productivity is low relative to other forests, but boreal forests provide habitat for fish, grazers, and birds, and are used by people for recreation, hunting, fishing, and timber. During the relatively brief (10,000 yr) history of the boreal forest in its current location, it has experienced radical changes in climate, vegetation, and fauna (Muhs et al. In press). Warming during the last 25 years (Serreze et al. 2000) has been associated with warming and melting of permafrost (Osterkamp and Romanovsky 1999), changes in growth rates of dominant trees (Juday et al. 2000), increased area burned (Kasischke et al. 1999), insect outbreaks (Malmstrom and Raffa 2000), and changes in vertebrate populations (Stephenson et al. In press). We do not yet know all the causal links among these changes, nor their implications for the functioning of the boreal forest and the people who inhabit this region. Research in the Bonanza Creek LTER focuses on documenting these changes, their causes and interactions, and their implications for regional sustainability (Chapin and Whiteman 1998).

The structure and functioning of the boreal forest determines and is influenced by its disturbance regime (Mann and Plug 1999). Millions of hectares of the Alaskan Interior burn each decade. The extent and distribution of these disturbances are changing rapidly as climate warms, as fire control is intensified near population centers (Kasischke et al. 1999), as timber harvest expands to meet the fiber needs of a growing human population (Melillo et al. 1996), and as insect outbreaks increase with climatic warming (Malmström and Raffa 2000). In order to understand the current and future structure, diversity, and functioning of the boreal forest, we must understand the interactions between changes in climate and disturbance regime.

Our research has important implications for the global system. The boreal forest contains 40% of the world's reactive soil carbon (McGuire et al. 1995). Boreal forests could be part of the "missing sink" of CO<sub>2</sub>, if they are accumulating carbon (Randerson et al. 1999) or a carbon source if recent warming trends enhance fire frequency or decomposition more than they enhance plant production (Zimov et al. 1999). The boreal forest also influences climate through regional energy exchange and the hydrologic cycle. The northward movement of the arctic treeline could amplify the expected rapid climatic warming at high latitudes (Bonan et al. 1995). Alternatively, increased deforestation or a shift from predominance of conifer to deciduous forest resulting from logging or fire could cause regional cooling (Chapin et al. 2000). The boreal forest accounts for 80% of the watershed area that drains into the Arctic Ocean. The quantity and salinity of water that moves from the Arctic Ocean to the North Atlantic influence deepwater formation and the strength of the thermohaline circulation that drives latitudinal heat transport by the earth's oceans. Changes in this circulation are implicated in past switches between glacial and interglacial periods. Thus, the boreal forest plays a critical but uncertain role in the future climate of the Earth.

There is evidence for both stability and rapid change in boreal ecosystems at all time scales. At large temporal and spatial scales, the boreal forest has responded sensitively to climate, with changes from birch-shrub tundra to poplar woodland (9,000 to 12,000 yr BP) to white spruce forest (5,000-9,000 yr BP) to a landscape mosaic with abundant black spruce forests (4,000-6,000 yr BP) (Edwards and Barker 1994). Fire frequency increased dramatically with the arrival of black spruce, despite the trend toward a cooler wetter climate at that time, indicating strong vegetation effects on fire regime. During the last 1,000 years, the vegetation has remained remarkably stable, despite large changes in climate, including the medieval warm period, the Little Ice Age, and recent warming to temperatures that are the warmest in 400 years (Overpeck et al. 1997). The apparent stability during the last millennium suggests that no new thresholds existed for new migrations. However, potential migrants, such as lodgepole pine, have already migrated the Alaskan border from the east and been planted in interior Alaska, so imminent future changes in forest dominants are plausible.

Abrupt changes in ecosystem functioning occur in Alaskan forest succession because there are only 1 or 2 dominant tree species in any one stand, and each of these species exerts strikingly different effects on ecosystem processes. Consequently, successional changes in forest dominants translate into strong autogenic control over biogeochemical and population processes. However, many of the processes that generate these repeatable patterns are stochastic and regionally variable. The boreal forest is constantly rebounding from a series of past "extreme" events. Stand-replacing fires occur every 40-200 yr (Mann and Plug 1999). White spruce recruitment following fire requires seed dispersal onto a mineral seedbed within 5-10 yr after fire. Good cone crops occur only every 3-10 yr, however and seeds disperse only modest distances. Plant mortality from herbivory (snowshoe hare, spruce budworm, larch sawfly, aspen tortix, birch spear-marked black moth) and snow-breakage events occur in pulses separated by years or decades. Together, these events introduce a stochastic element to vegetation dynamics that contributes to substantial variation in species composition and successional trajectory across the landscape.

## Conceptual Framework

The central question in the BNZ LTER research is: **How do changes in climate and disturbance regime alter the functioning of the Alaskan boreal forest?** Our overall objective is to document the major controls over community dynamics, biogeochemistry, and disturbance and their interactions in the face of a changing climate. The research is organized around three interactive themes: (1) **Forest dynamics**; (2) **The changing boreal carbon cycle**; and (3) **Regional and landscape controls over disturbance regime**.

The **forest dynamics** theme addresses successional changes in population and community processes following disturbance. We examine the relative importance of historical legacies, stochastic processes, and species effects (autogenic processes) in determining successional trajectories and the sensitivity of these trajectories to climate. An improved understanding of forest dynamics and their mechanistic controls is essential to management for forest products, wildlife, and forest health. **Changes in the carbon cycle** during succession hinge on changes in forest dynamics and other element cycles, but also influence nutrient availability and microenvironment and therefore successional changes in forest dynamics. Climate affects the carbon cycle directly through changes in net primary production and heterotrophic respiration and indirectly through changes in species composition and their effects on biogeochemistry. An improved understanding of the boreal carbon cycle is critical to projections of future changes in global carbon and climate dynamics. **Regional and landscape controls over disturbance regime** focuses on regional and landscape processes that are responsible for the timing, extent, and severity of disturbance. Disturbance regime is affected by and influences successional trajectories of forest dynamics and biogeochemistry. Understanding controls over disturbance regime is critical to long-term regional planning for sustainable use of natural resources.

## Research Design

Intensive sites. Our intensive research sites are at the Bonanza Creek Experimental Forest (BCEF), which is dissected by the glacially fed Tanana River, and the Caribou-Poker Creek Research Watershed (CPCRW), which has several well-defined upland watersheds. Our intensive studies focus on three chronosequences: succession following flooding in the Tanana River floodplain at BCEF, post-fire succession on south-facing uplands at BCEF, and post-fire succession on north-facing uplands at CPCRW. These sites enable us to compare primary and secondary succession and to compare post-fire succession in two dramatically different thermal and disturbance regimes. The floodplain-upland contrast allows us to compare a moisture-rich system (floodplains) with a moisture-limited upland system. The post-fire successional sequences allow us to compare warm, dry, south-facing slopes without permafrost to north-facing, permafrost-dominated slopes. For each of these sequences we study early, mid, and late successional sites, except in the floodplain, where the more complex successional dynamics require six successional stages. Each of these stages is replicated three times. In many of these intensive sites we have experiments to test the importance of particular processes. In each successional stage we measure microenvironment continuously, those population and ecosystem variables that respond sensitively to climate annually (e.g., litterfall and tree diameter increment), and slow variables (e.g., species composition and biomass) at 1-6 yr intervals depending on rate

of successional change. For those processes that occur most actively or have greatest impact in particular stages (e.g., establishment of tree seedlings and mammalian herbivory in early succession), we focus intensive effort on these stages and use less intensive observations at other stages.

Modeling. We use four types of models that operate across a range of spatial and temporal scales to integrate our results in time and space and as a mechanism for testing proposed linkages between pattern and process. (1) Stand-level population models include models of small mammal population dynamics and herbivory (Rexstad 1994) and an individual-based model of tree population dynamics [SKOG]. (2) Soil thermal and hydrologic models simulate permafrost temperatures and the probability of thermokarst within stands. (3) The Alaska Frame Based Ecosystem Code (ALFRESCO) is a landscape model based on the turning point theory of our previous LTER research. It simulates the interactions of climate, fire, and landscape structure in causing shifts in landscape structure and disturbance spread. (4) The high-latitude version of the Terrestrial Ecosystem Model (TEM), which simulates the major C and N fluxes and pools sizes of ecosystems, incorporates understanding gained from soil thermal and hydrology models. TEM has been applied at a variety of spatial scales (stand-level to regional) and temporal scales (seasonal to century) to evaluate the carbon dynamics of high latitude ecosystems.

Temporal scaling. To assess past interactions between climate, disturbance, and ecosystem properties, we focus on three time scales: (1) the last 300 years, during which climate has warmed (tree rings), (2) the last 1,000 years, which includes relatively rapid, low-magnitude climate changes of the LIA as recorded in lake cores, and (3) lower-resolution records from lake cores for the past 12,000 years, which includes the entire history of the boreal forest, including the period ca. 10,000-6000 yr B.P. when conditions were probably warmer and drier than present.

## **Major recent results**

### Environment

Upland and floodplain forests that we study in the BNZ LTER develop in fundamentally different geochemical environments and differ in the causes of nutrient limitation. The acidic upland soils are low in nitrogen due to N depletion by repeated fires. In contrast, the floodplain soils, which form from glacial silt, are strongly alkaline, due to surface evaporation (Yarie et al. 1998). These soils bind phosphorus and are inherently low in nitrogen, leading to strongly nutrient-limited plant growth in the early stages of succession. Disturbance regimes differ radically between upland and floodplain ecosystems, with upland landscape pattern controlled largely by fire (Kasischke et al. 1999) and floodplains responding to fluvial processes (Yarie et al. 1998, Adams 1999).

Microclimate in the boreal forest differs dramatically between north- and south-aspect slopes, due to large differences in solar radiation and soil temperature, allowing us to study the impact of climate on ecosystem processes under conditions where other state factors are held relatively constant. Permafrost, which is generally present on north-facing slopes and valley bottoms (but absent on south-facing slopes) dramatically reduces rates of biogeochemical cycling, nutrient supply, and forest productivity (Van Cleve et al. 1991). Permafrost temperatures were relatively stable from the 1950s to the

mid-1970s, but have increased in response to the recent warming (Osterkamp and Romanovsky 1999). In ice-rich sites, melting of permafrost has caused widespread thermokarst (slumping of the ground surface), causing large changes in soil moisture and temperature.

Following a gradual cooling over the last 1,000 years, the Alaskan climate has warmed since about 1850, and more dramatically since the mid-1970s, due to changes in atmospheric circulation, perhaps superimposed on greenhouse warming, (Serreze et al. 2000). Tree-ring analysis shows that this warming is unprecedented in the past 200 years (Barber et al. 2000). The average annual area burned has doubled in boreal North America in the last ten years, in parallel with the warming trend (Kasischke et al. 1999). Lake cores suggest that the fire return time in the 20<sup>th</sup> century is only half as long as the average for the last 1000 years. The increase in early successional deciduous vegetation caused by fire increases regional albedo and evapotranspiration and reduces sensible heat transfer to the atmosphere. This acts as a negative feedback to regional warming (Chapin et al. 2000a).

In summary, changes in the Earth's Climate System have led to pronounced warming in the Alaskan boreal forest, causing melting of permafrost, increased fire frequency, and fire-induced vegetation changes that may cause a negative feedback to regional warming. As discussed below, forest dynamics and biogeochemical cycling play a critical role in this interaction between the boreal forest and climate.

### Forest Dynamics

The differences in environment and disturbance regime between upland and floodplain and between north- and south-facing slopes promote colonization by different plant species, leading to different successional trajectories (Yarie et al. 1998). [See detailed vegetation descriptions on the BNZ website.] Following plant colonization in this low-diversity biome, the successional change in dominant forest species results in dramatic threshold changes in the physical and chemical environment. For example, alder invasion in early succession increases nitrogen availability and productivity (Uliassi et al. In press, Uliassi and Ruess Submitted). The late-successional change from deciduous trees to spruce alters the physical structure of litter, allowing the establishment of mosses. These mosses insulate the soil and greatly reduce soil temperature, decomposition rate, and nitrogen supply (Van Cleve et al. 1996). The switch to the moss-conifer-dominated ecosystem, dramatically increases flammability and probability of fire (Rupp et al. submitted). These **turning points** associated with changes in the dominant tree species are some of the most dramatic examples of species effects on ecosystem processes that have been reported and are likely to occur in many low-diversity ecosystems (Chapin et al. 2000b).

Succession produces repeatable patterns in species diversity (Rees 1997, Waide et al. 1999), with hot spots of insect and bird diversity in early successional floodplain stands (Johnson unpubl.) and nonvascular diversity increasing in late successional spruce forests (Willsrud 1997). Early successional plants exhibit a broad spectrum of tannins that have species-specific effects on insect herbivores (Ayres et al. 1997). The resulting host specificity contributes to the high insect diversity in early succession. Climate and land use are the global-change drivers that will probably have the greatest

impact on boreal diversity over the next century (Rees 1997, Chapin and Danell In press, Sala et al. 2000).

Mammalian herbivores strongly influence the rate of successional change. Selective browsing by moose and hares on pioneer willows leads to the competitive release of mid-successional species such as alder and poplar (Kielland and Osborne 1998) and accelerates successional change (Kielland and Bryant 1998). The browsing-induced reduction in canopy density has cascading effects on nutrient cycling through changes in physical environment, litter chemistry, and the proportion of nutrients returned as feces (Kielland et al. 1998, Kielland and Bryant 1998). Moose account for a third of the aboveground nitrogen input to soils in the willow stage (Kielland and Bryant 1998), indicating a key role of herbivory in the biogeochemistry of early succession. Herbivory also connects riparian and stream ecosystems. Winter browsing of birch by moose changes the chemistry of leaves in the following growing season, increasing the quality of dissolved organic carbon (DOC) leachates derived from the leaf litter, in turn, increasing use of DOC by stream microorganisms (Estensen et al. in review).

Coarse-resolution analysis of Holocene pollen cores indicates that regional expansion of white spruce ca 8500 yr BP and of black spruce 4500 yr BP coincided with increased effective moisture. This is consistent with LTER dendroecological data indicating strong moisture limitation to white spruce growth (Barber et al. 2000). The black spruce expansion was accompanied by increased charcoal, suggesting a vegetation-induced increase in fire frequency, despite the wetter climate (J. Clark, unpubl.). This surprising result indicates a pronounced effect of vegetation on fire regime.

In summary, topographic differences in physical environment and disturbance regime give rise to strikingly different suites of initial colonizers and successional trajectories between floodplains and north- and south-aspect uplands. The pattern of species change after colonization is controlled by herbivory and by strong plant species effects on the soil physical environment, biogeochemistry (see below), and disturbance regime. These strong species effects reflect the low functional diversity of trees in boreal forest and their interaction with understory mosses.

### Production and Biogeochemistry

Tree ring-climate correlations, carbon isotope analyses, and experimental manipulation of water and nitrogen suggest that, despite the cold climate, water and nitrogen primarily limit the productivity of upland white spruce stands (Barber et al. 2000, Billings 1998). Allocation, however, is responsive to temperature. Alaskan interior forests have the highest allocation to root production of any forest yet reported. This high proportion of total ecosystem C allocated below ground contributes to large soil C stocks. Most soil respiration is derived from root rather than heterotrophic respiration (Ruess et al. 1998). Approximately three times more N is cycled through fine roots than through aboveground litterfall. These studies indicate the critical role of the belowground environment in explaining patterns of production.

Successional changes in vegetation dramatically alter carbon and nutrient turnover. In the floodplain, for example, nitrogen fixers add nitrogen and organic matter (Uliassi et al. In press, Uliassi and Ruess Submitted), which acidifies the soil and increases the availability of both N and P. When poplars dominate, their tannins cause a

decline in N<sub>2</sub>-fixation, but provide sufficient labile C to enhance N mineralization (Schimel et al. 1998) and N supply to vegetation. As spruce replaces poplar, the increase in lignin content, C:N ratio, and lignin:N ratio and the moss-induced decline in soil temperature together reduce decomposition and N mineralization (Yarie et al. 1998). These are among the best-documented examples of vegetation-driven changes in biogeochemistry.

Vertebrate herbivory also affects soil processes. The warm dry soils of heavily browsed early successional sites have higher rates of soil respiration and higher decomposition potentials than do browser-free exclosures (Kielland et al. 1997). The high decomposition rates in browsed areas reflects increased labile C and N concentrations in litter (Kielland et al. 1997) and increased root turnover (Kielland et al. 1997, Ruess et al. 1998). The combination of reduced fine root biomass (Rossow et al. 1997) and increased root turnover in browsed areas leads to a reduction in soil C content outside the exclosures.

The biogeochemistry of Alaskan boreal forests has important implications for trace-gas feedbacks to the atmosphere. Upland Alaskan forests are a sink for atmospheric methane. N addition inhibits CH<sub>4</sub> consumption at some sites but not others, due to site differences in CH<sub>4</sub> oxidizer populations rather than to differences in N cycling (Gulledge and Schimel 1998b, Gulledge and Schimel 1998a, Gulledge et al. 1998). This work is one of the strongest examples of ecosystem processes being controlled by the structure of the microbial community. Models based on LTER research suggest that interior Alaska is currently a net sink of CO<sub>2</sub> (McGuire and CCMLP Submitted, Yarie and Billings Submitted) but that interannual variation in climate and disturbance strongly affect the direction and magnitude of carbon exchange (McGuire and CCMLP In press).

In summary, the major state factors (climate, topography, parent material, biota, and time) each exert strong effects on ecosystem processes in the boreal forest, leading to important interactions among microclimate, soil resources, functional types of organisms, and disturbance regime. The vegetation-driven changes in biogeochemistry are critically important in explaining patterns of successional change.

### Hydrology and Aquatic Processes

Permafrost is a major "ecological adjective" modifying hydrology, thermal regimes, chemical fluxes from uplands to streams, and biotic processes in streams (Oswood 1997). Stream flow from permafrost-dominated watersheds has more dissolved organic C but less dissolved minerals than in permafrost-free watersheds (MacLean et al. 1999). Permafrost apparently acts as a partial barrier to percolation of water from organic soil horizons to underlying mineral soils and so generates rapid storm-flows rich in dissolved organic C but relatively impoverished in dissolved minerals (MacLean et al. 1999). The recent warming and melting of permafrost has important implications for the coupling of land-water systems at high latitudes.

## **1.1 Regionalization**

We have developed regional data sets of input parameters required for regional modeling. Maps of climate (Mock et al. 1998, Fleming et al. 2000) document the

geographic pattern of warming from the 1960s to the 1980s. Decadal maps of fires since 1950 (Kasischke In press) and of lightning strikes (Dissing and Verbyla submitted) suggest an increase annual area burned in western Canada (but not in Alaska) in the last decade (Kasischke et al. 1999), presumably due to warmer temperatures and lower fuel moisture. Bark beetles have eliminated spruce forests over broad areas of southern Alaska in association with recent warming but have not yet reached outbreak proportions in interior Alaskan forests (McCullough et al. 1998, Malmström and Raffa 2000). Our 20-year population record of major insect defoliators indicates high populations of several insect defoliators in BCEF within the past decade. An examination of the spatial distributions of Alaskan freshwater fishes using 2 frameworks, ecoregions and hydroregions (drainage basins), showed that the distribution of Alaskan freshwater fishes is complexly determined by ecophysiological requirements of fishes along the latitudinal gradient from northern rain forest to arctic tundra, by current and past barriers to dispersal, and by the legacy of Pleistocene glaciation (Oswood et al. 2000).

A 200-yr chronology of river height developed from correlations of river height at LTER sites (1989 – present) and USGS gauging stations (1962 – present) and a 200-yr ring-width chronology for the floodplain (Yarie et al. 1998, Adams 1999) indicate large variation in flood frequency but no directional trend.

### **Synthesis and Modeling**

Our modeling has used LTER data on ecosystem processes to develop and parameterize models as a basis for extrapolating results to the regional scale. For example, a carbon balance model parameterized from black spruce data in Alaska reproduces the seasonal and interannual variation in net ecosystem carbon exchange in the BOREAS old black spruce sites in Canada (Amthor et al. In press, Clein et al. In press, Potter et al. Submitted). We then apply these models at larger scales to estimate the current carbon budget of Alaska (McGuire and CCMLP In press, Yarie and Billings Submitted) and future scenarios of carbon storage at the circumpolar scale (McGuire et al. In press-b, Clein et al. In press). We have also used these models to explore the role of winter ecosystem processes of high-latitude ecosystems in seasonal aspects of the global carbon cycle (McGuire et al. In press-b). Sensitivity analyses with these models highlight the importance of: (1) root dynamics and labile soil carbon in C-budget models; (2) vegetation structure (specifically trees and moss) in soil thermal models; and (3) C-N interactions in predicting future forest productivity. Changes in vegetation caused by climatic warming could have profound regional effects on landscape processes, including fire spread, seed dispersal and feedbacks to climate. We document these changes through remote sensing and explore their consequences through landscape-scale modeling of fire-climate-vegetation interactions (Rupp et al. 2000, Rupp et al. In press a, Inpress b).

We have integrated our research into a larger context through participation in many LTER cross-site comparisons and through a synthesis of high-latitude ecosystem feedbacks to climate involving comparisons of ARC and BNZ LTER sites and the BOREAS sites in Canada (Chapin et al. 2000). Together with HJA, we have contributed to an effort by the US Vice President and Russian Prime Minister to develop ILTER sites in Russia.

## **Summary**

Research at the BNZ LTER site has contributed substantively to understanding the relationship between “independent” state factors and internal ecosystem dynamics in causing successional change. We have shown that:

1. Species effects are strong in the boreal forest.
2. Successional changes in species composition are not a simple consequence of changes in competitive balance but involve species-driven changes in biogeochemistry and the physical environment.
3. Vertebrate herbivores are a powerful force driving successional change through their effects on plant competitive interactions and biogeochemistry.
4. Succession influences exchanges of CH<sub>4</sub>, CO<sub>2</sub>, water, and energy in ways that could feed back to climate.

## **Outreach efforts**

The BNZ LTER has substantially expanded its efforts at outreach in the areas of K-12 education, development of formal ties with other research programs, museums and agencies, and organization of science symposia. We have hired a site manager (a new position), one of whose responsibility will be to augment our outreach to the general public.

## Education

As part of the LTER schoolyard program, we have teamed up with two ongoing science education programs, GLOBE (NASA) and Partners in Science to train science teachers in 15 Alaskan towns and villages. LTER funding enabled six Fairbanks elementary and high school teachers to be added to the program. We have initially focused attention on teachers in close proximity to our LTER site to explore how best to integrate education with our research program.

In addition to the formal LTER schoolyard program, individual LTER PIs have taught short courses for secondary school science teachers from rural Alaska (Oswood and Bryant), developed web-based curricula in long-term ecological monitoring (Verbyla, Sparrow, and Juday), worked in rural schools to describe the LTER science program (Lloyd), taught about LTER science in local environmental summer camps for grade school students (Rexstad), involved high school students in LTER research projects (Ruess and Chapin), taught lessons in climatology and helped establish climate and soil monitoring stations in local schools (Hinzman), and acted as judges for the local elementary and secondary school science fairs (many PIs).

## Ties with other LTER sites

The BNZ provides a logical comparison with many other LTER sites, particularly the vegetation types that are immediately north (Arctic [ARC] LTER site) and south (HJ Andrews [HJA] LTER site). We have worked closely with these two sites to develop programs that will maximize the opportunities for comparative studies. Our collaborations with the Arctic LTER site are directed towards understanding Alaska as a regional system in which the boreal forest and tundra are linked by many common biotic components and by the atmosphere. We are developing museum collections and a sample archive that will serve both the ARC and BNZ sites. With HJA we are developing common protocols in studies of hydrology and vegetation feedbacks to climate.

## Ties with Alaskan long-term ecological research programs

Our LTER science symposia and active solicitation of collaborations with agencies have created closer links with several long-term ecological research programs in Alaska. We are collaborating with the Long-Term Ecological Monitoring (LTEM) program of the National Park Service to use the same regional sampling protocols, hierarchical vegetation classifications, and climate monitoring programs. Two LTER investigators (Rexstad and Juday) also work in the LTEM, providing direct communication between the two programs.

Collaborative arrangements provide the LTER access to population and habitat data from the Alaska Department of Fish and Game (ADF&G). We are developing a GIS database of previous forest harvests with the Alaska Division of Forestry (DOF). We worked with the EROS data center of USGS to develop statewide maps of climate, vegetation, and other variables at the 1-km scale. The BNZ LTER collaborated with the Alaska Fire Service (AFS), a section of BLM, to burn a 740 ha watershed in CPCRW in July 1999 (FROSTFIRE). As follow-up, the LTER initiated regular seminars allowing interchange between scientists from LTER and agencies (AFS, ADF&G, DOF, etc.). An explicit objective of these seminars is the development of models that link climate, fire, post-fire succession, and wildlife habitat. AFS has offered to do additional prescribed burns to meet LTER science needs. Our long-term goal is to identify and make accessible all the long-term data bases in Alaska that are useful for ecological modeling. We provide links to agency web sites where data are available, provide on our web site a list of data sets and contact information, or will post these data on our web site, as a last resort.

#### Ties with museum collections

Using LTER supplement funding, we have worked with the University of Alaska Museum to develop collections of plants (herbarium specimens and tissue collections), insects, and vertebrates that provide both a long-term record and a broad spatial record of genetic and species diversity of Alaska. We have also initiated discussions with them about how to proactively design the optimal long-term collections program, rather than to be passive recipients of specimens that are brought to the museum. We anticipate a strengthening of this tie with the Museum, as we strengthen the biodiversity component in our regionalization studies.

#### Involvement in forest management issues

In 1997, we held a workshop on the ecological role of forest harvest in interior Alaskan forests. This workshop presented perspectives from state and federal land managers, native groups, commercial interests, and ecologists. We developed a conceptual model of the role of human activities as an integral component of the boreal forest and determined that, in the next two decades, human decisions about fire control would have much greater impact on the boreal forest than would forest harvest. We seek external funding to explore the role of humans as components of the Alaskan regional system. We plan a second symposium on forest harvest. Wurtz occupies the Forest Science seat on the Citizens' Advisory Committee for the 1.7 million-acre Tanana Valley State Forest. Juday has participated in training sessions for the Alaska Division of Forestry, the Bureau of Land Management, and the National Park Service. Several LTER scientists have contributed to articles sponsored by the Society of American Foresters in the local newspaper and to the occasional newsletter "Forest Science Notes" published by the UAF Dept. of Forest Science.

#### Outreach to the general public

LTER scientists (Juday, Romanovsky, Chapin, Finney, and others) have been interviewed by numerous radio and television stations (NBC, CBS, ABC, public television and radio, Danish Broadcasting System) and newspapers (New York Times,

local Alaskan newspapers) about the impact of global warming on boreal forests. Juday was an invited speaker in the Congressional Seminar series, sponsored by U.S. Global Change Research Program, Washington. The audience included members of Congress and staff, constituencies involved in U.S. global change policy, and agencies involved in global change research. NOVA film crews interviewed LTER scientists and filmed the FROSTFIRE experimental burn as part of a major television series on the ecological role of fire. Hinzman led four public meetings to explain the science of the Frostfire project.

## Literature cited

### Literature Cited

- Adams, P. C. 1999. The dynamics of white spruce populations on a boreal river floodplain. PhD Dissertation. Duke University.
- Amthor, J.S., J.M. Chen, J.S. Clein, S.E. Froking, R.F. Grant, J.S. Kimball, A.W. King, A.D. McGuire, N.T. Nikolov, C.S. Potter, and S. Wang. 2000.(in press) Comparing hourly, daily, monthly, and annual CO<sub>2</sub> and water vapor exchange of a boreal forest predicted by nine ecosystem process models: Model results and relationships to measured fluxes. *Journal of Geophysical Research - Atmospheres*.
- Ayres, M. P., T. P. Clausen, S. J. MacLean, A. M. Redman, and P. B. Reichardt. 1997. Diversity of structure and antiherbivore activity in condensed tannins. *Ecology* 78:1696-1712.
- Barber, V. A., G. P. Juday, and B. P. Finney. 1998. Tree-ring data for climate reconstruction and indication of twentieth century warming and summer drying. *Paleotimes* 6:20-22.
- Billings, S. A. 1998. Effects of rainfall exclusion on soil carbon gases and water relations in two boreal forest ecosystems. PhD. Duke University.
- Bonan, G. B., F. S. Chapin, III, and S. L. Thompson. 1995. Boreal forest and tundra ecosystems as components of the climate system. *Climatic Change* 29:145-167.
- Chapin, F. S., III, and K. Danell. In press. Scenarios of biodiversity change in the boreal forest. Pages in F. S. Chapin, III, O. Sala, and E. Huber-Sannwald, editors. *Scenarios of future biodiversity*. Springer-Verlag, New York.
- Chapin, F.S., III., Eugster, W., McFadden, J.P., Lynch, A.H., and Walker, D.A. 2000. Summer differences among arctic ecosystems in regional climate forcing. *Journal of Climate*, 13: 2002-2010.
- Chapin, F.S., III, McGuire, A.D., Randerson, J., Pielke, R., Sr., Baldocchi, D., Hobbie, S.E., Roulet, N., Eugster, W., Kasischke, E., Rastetter, E.B., Zimov, S.A., and Running, S.W. 2000a. Arctic and boreal ecosystems of western North America as components of the climate system. *Global Change Biology* 6(Suppl. 1): 211-223.
- Chapin, F.S., III, E.S. Zaveleta, V.T. Eviner, R.L. Naylor, P.M. Vitousek, S. Lavorel, H.L. Reynolds, D.U. Hooper, O.E. Sala, S.E. Hobbie, M.C. Mack, and S. Diaz. 2000b. Consequences of changing biotic diversity. *Nature* 405: 234-242.
- Chapin, F. S., III, and G. Whiteman. 1998. Sustainable development of the boreal forest: interaction of ecological, social and consumer feedbacks. *Conservation Ecology* 2:
- Clein, J. S., B. L. Kwiatkowski, A. D. McGuire, J. E. Hobbie, E. B. Rastetter, J. M. Melillo, and D. W. Kicklighter. In press. Modeling carbon responses of tundra ecosystems to historical and projected climate. I. A comparison of a regional- and

- a global-scale ecosystem model applied to the Kuparuk Basin. *Global Change Biology*
- Dissing, D. and D. L. Verbyla. Submitted. Landscape Interactions With Thunderstorms in Interior Alaska. *Landscape Ecology*.
- Edwards, M. E., and E. D. Barker, Jr. 1994. Climate and vegetation in northeastern Alaska 18,000 yr B.P - present. *Palaeogeography, Palaeoclimatology, Palaeoecology* 109:127-135.
- Fleming, M., Chapin, F.S., III, Cramer, W., Hufford, G., and Serreze, M.C. 2000. Geographic patterns and dynamics of Alaskan climate interpolated from a sparse station record. *Global Change Biology* 6(Suppl. 1): 49-58
- Gulledge, J., and J. P. Schimel. 1998a. Low-concentration kinetics of atmospheric CH<sub>4</sub> oxidation in soil and mechanism of NH<sub>4</sub><sup>+</sup> inhibition. *Applied and Environmental Microbiology* 64:4291-4298.
- Gulledge, J., and J. P. Schimel. 1998b. Moisture control over atmospheric CH<sub>4</sub> consumption and CO<sub>2</sub> production in physically diverse soils. *Soil Biology and Biochemistry* 30:1127-1132.
- Gulledge, J., P. A. Steudler, and J. P. Schimel. 1998. Effect of CH<sub>4</sub> starvation on atmospheric CH<sub>4</sub> oxidizers in taiga and temperate forest soils. *Soil Biology and Biochemistry* 30:1463-1467.
- Jenny, H. 1941. *Factors of soil formation*. McGraw-Hill, New York.
- Kasischke, E. S. In press. Fire, climate change, and carbon cycling in Alaskan boreal forests. Pages in J. L. Levine, editors. *Biomass burning and climate change*. MIT Press, Cambridge.
- Kasischke, E. S., K. Bergen, R. Fennimore, F. Sotelo, G. Stephens, A. Janetos, and H. H. Shugart. 1999. Satellite imagery gives a clear picture of Russia's boreal forest fires. *EOS- Transactions of the American Geophysical Union* 80:141, 147.
- Kielland, K., B. Barnette, and D. Schell. 1998. Intra-seasonal variation in the <sup>15</sup>N signatures of taiga trees and shrubs. *Canadian Journal of Forest Research* 28:485-488.
- Kielland, K., and J. Bryant. 1998. Moose herbivory in taiga: effects on biogeochemistry and vegetation dynamics in primary succession. *Oikos* 82:377-383.
- Kielland, K., J. P. Bryant, and R. W. Ruess. 1997. Mammalian herbivory and carbon turnover in early successional stands in interior Alaska. *Oikos* 80:25-30.
- Kielland, K., and T. Osborne. 1998. Moose browsing on feltleaf willow: optimal foraging in relation to plant morphology and chemistry. *Alces* 34:149-155.
- MacLean, R.M., Oswood, M.W., Irons, J.G., III., and McDowell, W.H. 1999. The effect of permafrost on stream biogeochemistry: a case study of two streams in the Alaskan (U.S.A.) taiga. *Biogeochemistry*, 47: 239-267.
- Malmstrom, C.M., and Raffa, K.F. 2000. Response of boreal forest to climate change: the role of insect herbivores and plant pathogens. *Global Change Biology*. 6(Suppl. 1): 35-48.
- Mann, D. H., and L. J. Plug. 1999. Vegetation and soil development at an upland taiga site, Alaska. *Ecoscience* 6:272-285.
- McCullough, D. G., R. A. Werner, and D. Neumann. 1998. Fire and insects in northern and boreal forest ecosystems of North America. *Annual Review of Entomology* 43:107-127.
- McGuire, A.D., and CCMLP. (in press). CO<sub>2</sub>, climate and land-use effects on the terrestrial carbon balance, 1920-1992. *Global Geochemical Cycles*.
- McGuire, A. D., J. M. Melillo, J. T. Randerson, W. J. Parton, M. Heimann, R. A. Meier, J. S. Clein, D. W. Kicklighter, and W. Sauf. In press-b. Modeling the effects of snowpack on heterotrophic respiration across northern temperate and high latitude regions: Comparison with measurements of atmospheric carbon dioxide in high latitudes. *Biogeochemistry*

- McGuire, A. D., J. W. Melillo, D. W. Kicklighter, and L. A. Joyce. 1995. Equilibrium responses of soil carbon to climate change: empirical and process-based estimates. *Journal of Biogeography* 22:785-796.
- Melillo, J. M., I. C. Prentice, G. D. Farquhar, E.-D. Schulze, and O. E. Sala. 1996. Terrestrial biotic responses to environmental change and feedbacks to climate. Pages 445-481 in J. T. Houghton, L. G. Meira Filho, B. A. Callander, N. Harris, A. Kattenberg, and K. Maskell, editors. *Climate change 1995. The science of climate change*. Cambridge University Press, Cambridge.
- Mock, C. J., P. J. Bartlein, and P. M. Anderson. 1998. Atmospheric circulation patterns and spatial climate variations in Beringia. *International Journal of Climatology* 10:1085-1104.
- Muhs, D., T. Ager, and J. Beget. In press. Vegetation and paleoclimate of the last interglacial period, central Alaska. *Quaternary Science Reviews*
- Osterkamp, T. E., and V. E. Romanovsky. 1999. Evidence for warming and thawing of discontinuous permafrost in Alaska. *Permafrost and Periglacial Processes* 10:17-37.
- Oswood, M.W., J.B. Reynolds, J.G. Irons III, A.M. Milner. 2000. Distributions of freshwater fishes in ecoregions and hydroregions of Alaska. *Journal of the North American Benthological Society* 19:405-418
- Oswood, M. W. 1997. Streams and rivers of Alaska: a high latitude perspective on running waters. Pages 331-356 in A. M. Milner, and M. W. Oswood, editors. *Freshwaters of Alaska: ecological syntheses*. Springer-Verlag, New York.
- Overpeck, J., K. Hughen, D. Hardy, R. Bradley, R. Case, M. Douglas, B. Finney, K. Gajewski, G. Jacoby, A. Jennings, S. Lamoureux, A. Lasca, G. MacDonald, J. Moore, M. Retelle, S. Smith, A. Wolfe, and G. Zielinski. 1997. Arctic environmental change of the last four centuries. *Science* 278:1251-1256.
- Potter, C. S., J. S. Amthor, A. W. King, J. M. Chen, J. Liu, S. E. Frolking, R. F. Grant, S. Wang, J. S. Kimball, S. W. Running, A. D. McGuire, and J. Clein. Submitted. Comparison of boreal ecosystem model sensitivity to variability in climate and forest site parameters. *Journal of Geophysical Research*
- Randerson, J. T., C. B. Field, I. Y. Fung, and P. P. Tans. 1999. Increases in early season net ecosystem uptake explain changes in the seasonal cycle of atmospheric CO<sub>2</sub> at high northern latitudes. *Geophysical Research Letters* 26:2765-2768.
- Rees, D. C. 1997. Plant species diversity and forest structure on logged and burned sites in central Alaska. MS Thesis. University of Alaska, Fairbanks.
- Rossow, L. J., J. P. Bryant, and K. Kielland. 1997. Effects of above-ground browsing by mammals on mycorrhizal infection in an early successional taiga ecosystem. *Oecologia* 110:94-98.
- Ruess, R. W., R. L. Hendrick, and J. P. Bryant. 1998. Regulation of fine root dynamics by mammalian browsers in early successional Alaskan taiga forests. *Ecology* 79:2706-2720.
- Rupp, T. S., F. S. Chapin, III, and A. M. Starfield. In press-a. Response of subarctic vegetation to transient climatic change on the Seward Peninsula in northwest Alaska. *Global Change Biology*
- Rupp, T.S., F.S. Chapin, III, and A.M. Starfield. In press-b. Modeling the influence of topographic barriers on treeline advance at the forest-tundra ecotone in northwestern Alaska. Climatic Change.**
- Rupp, T. S., A. M. Starfield, and F. S. Chapin, III. 2000. A frame-based spatially explicit model of subarctic vegetation response to climatic change: comparison with a point model. *Landscape Ecology* 15:383-400.
- Rupp, T.S., Starfield, A.M., Chapin F.S. III, and Duffy P. Submitted. Modeling the impact of black spruce on the fire regime of Alaskan boreal forest. *Canadian Journal of Forest Research*.

- Sala, O.E., F.S. Chapin, III, J.J. Armesto, E. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sanwald, L.F. Huenneke, R. Jackson, A. Kinzig, R. Leemans, D. Lodge, H.A. Mooney, M. Oesterheld, N.L. Poff, M.T. Sykes, B.H. Walker, M. Walker, and D.H. Wall. 2000. Global biodiversity scenarios for the year 2100. *Science* 287:1770-1776.
- Schimel, J. P., R. G. Cates, and R. Ruess. 1998. The role of balsam poplar secondary chemicals in controlling nutrient dynamics through succession in the Alaskan taiga. *Biogeochemistry* 42:221-234.
- Serreze, M. C., J. E. Walsh, F. S. Chapin, III, T. Osterkamp, M. Dyrgerov, V. Romanovsky, W. C. Oechel, J. Morison, T. Zhang, and R. G. Barry. 2000. Observational evidence of recent change in the northern high-latitude environment. *Climatic Change* 46:159-207.
- Stephenson, R. O., S. C. Gerlach, R. D. Guthrie, C. R. Harrington, R. O. Mills, and G. Hare. In press. Wood bison (*Bison bison athabasca*) in late Holocene Alaska and adjacent Canada: paleontological, archaeological and historical records. Pages in S. C. Gerlach, and M. Murray, editors. *Zooarchaeology in the North: people and animals in Alaska, the arctic and northwest North America*.
- Uliassi, D. D., K. Huss-Danell, R. W. Ruess, and K. Doran. In press. Biomass allocation and nitrogenase activity in *Alnus tenuifolia*: responses to successional soil type and phosphorus availability. *Ecoscience*
- Uliassi, D. D., and R. W. Ruess. Submitted. The regulation of symbiotic nitrogen fixation by thinleaf alder in primary successional forests of the Tanana River floodplain. *Ecology*
- Van Cleve, K., F. S. Chapin, III, C. T. Dryness, and L. A. Viereck. 1991. Element cycling in taiga forest: State-factor control. *BioScience* 41:78-88.
- Van Cleve, K., L. A. Viereck, and C. T. Dyrness. 1996. State factor control of soils and forest succession along the Tanana River in interior Alaska, U.S.A. *Arctic and Alpine Research* 28:388-400.
- Waide, R. B., M. R. Willig, G. Mittelbach, C. Steiner, L. Gough, S. I. Dodson, G. P. Juday, and R. Parmenter. 1999. The relationship between productivity and species richness. *Annual Review of Ecology and Systematics* 30:257-300.
- Whittaker, R. H. 1975. *Communities and ecosystems*. Macmillan, New York.
- Willsrud, S. A. 1997. Moss communities across successional gradients in the Bonanza Creek Experimental Forest, interior Alaska. M.S. University of Alaska, Fairbanks.
- Yarie, J., and S. Billings. Submitted. Carbon balance of the taiga forest within Alaska. *Forest Ecology and Management*
- Yarie, J., L. Viereck, K. Van Cleve, and P. Adams. 1998. Flooding and ecosystem dynamics along the Tanana River. *BioScience* 48:690-695.
- Zimov, S. A., S. P. Davidov, G. M. Zimova, A. I. Davidova, F. S. Chapin, III, and M. C. Chapin. 1999. Contribution of disturbance to high-latitude amplification of atmospheric CO<sub>2</sub>. *Science* 284:1973-1976.

### **LTER Publications (1998-2000)**

[We include 1998-2000 because this is the final year of this two-year grant.]

#### Journal Articles

- Amthor, J.S., J.M. Chen, J.S. Clein, S.E. Froking, R.F. Grant, J.S. Kimball, A.W. King, A.D. McGuire, N.T. Nikolov, C.S. Potter, and S. Wang. 2000.(in press)  
Comparing hourly, daily, monthly, and annual CO<sub>2</sub> and water vapor exchange of a boreal forest predicted by nine ecosystem process models: Model results and

- relationships to measured fluxes. *Journal of Geophysical Research - Atmospheres*
- Aerts, R., and Chapin, F.S., III. 2000. The mineral nutrition of wild plants revisited: a re-evaluation of processes and patterns. *Advances in Ecological Research* 30:1-67.
- Arft, A.M., Walker, M.D., Gurevitch, J., Alatalo, J.M., Bret-Harte, M.S., Dale, M., Diemer, M., Gugerli, F., Henry, H.R., Jones, M.H., Hollister, R.D., Jónsdóttir, I.S., Laine, K., Lévesque, E., Marion, G.M., Molau, U., Mølgaard, P., Nordenhäll, U., Rashivin, V., Robison, C.H., Starr, G., Stenström, A., Stenström, M., Totland, Ø., Turner, P.L., Walker, L.J., Webber, P.J., Welker, J.M., and Wookey, P.A. 1999. Responses of tundra plants to experimental warming: meta-analysis of the International Tundra Experiment. *Ecological Monographs*, 69(4): 491-511.
- Barber, V.A., and Finney, B.P. In press. Late Quaternary paleoclimatic reconstructions for interior Alaska based on paleolake-level data and hydrologic models. *Journal of Paleolimnology*.
- Barber, V.A., Juday, G.P., and Finney, B.P. 1998. Tree-ring data for climate reconstruction and indication of twentieth century warming and summer drying. *PALEOTIMES*, VI (Spring/Summer): 20-22.
- Barber, V.A., Juday, G.P., and Finney, B.P. 2000. Reduced growth of Alaskan white spruce in the twentieth century from temperature-induced drought stress. *Nature* 405: 668-673.
- Begét, J. In press. Continuous late Quaternary paleoclimate proxy records from loess in Beringia. *Quaternary Science Reviews*.
- Binkley, D., Y. Son, and D.W. Valentine. 2000. Do forests receive occult inputs of nitrogen? *Ecosystems* 3(4):321-331.
- Billings, S. S., and J. Yarie. 2000. Sensitivity of soil methane fluxes to reduced precipitation in boreal forest soils. *Soil Biology and Biochemistry*
- Boles, S.H., and Verbyla, D.L. 1999. Effect of scan angle on AVHRR fire detection accuracy in interior Alaska. *International Journal of Remote Sensing* 20: 3437-3443.
- Boles, S., and Verbyla, D.L. 2000. Comparison of three AVHRR-based fire detection algorithms for interior Alaska. *Remote Sensing of Environment*. 72:1-16.
- Cater, T.C., and F.S. Chapin, III. 2000. Differential species effects on boreal tree seedling establishment after fire: resource competition or modification of microenvironment. *Ecology* 81:1086-1099.
- Chapin, F.S., III, McGuire, A.D., Randerson, J., Pielke, R., Sr., Baldocchi, D., Hobbie, S.E., Roulet, N., Eugster, W., Kasischke, E., Rastetter, E.B., Zimov, S.A., and Running, S.W. 2000. Arctic and boreal ecosystems of western North America as components of the climate system. *Global Change Biology* 6(Suppl. 1): 211-223.
- Chapin, F.S., III., and Whiteman, G. 1998. Sustainable development of the boreal forest: interaction of ecological, social and consumer feedbacks. *Conservation Ecology*, 2: 12. (Online at <http://www.consecol.org/vol2/iss2/art12>).
- Chapin, F.S., III., Sala, O.E., Burke, I.C., Grime, J.P., Hooper, D.U., Lauenroth, W.K., Lombard, A., Mooney, H.A., Mosier, A.R., Naeem, S., Pacala, S.W., Roy, J., Steffen, W.L., and Tilman, D. 1998. Ecosystem consequences of changing biodiversity. *Bioscience*, 48: 45-52.
- Chapin, F.S., III, E.S. Zaveleta, V.T. Eviner, R.L. Naylor, P.M. Vitousek, S. Lavorel, H.L. Reynolds, D.U. Hooper, O.E. Sala, S.E. Hobbie, M.C. Mack, and S. Diaz. 2000b. Consequences of changing biotic diversity. *Nature* 405: 234-242.
- Child, J., Begét, J., and Werner, A. 1998. Three Holocene tephras identified in lacustrine sediment cores from the Wonder lake area and Preserve, Alaska, U.S.A. *Arctic and Alpine Research*, 30: 89-95.
- Clein, J.S., McGuire, A.D., Zhang, X., Kicklighter, D.W., Melillo, J.M., Wofsy, S.C., and Jarvis, P.G. (in press). The role of nitrogen dynamics in modeling historical and

- projected carbon balance of black spruce ecosystems across North America: comparisons with CO<sub>2</sub> fluxes measured in the Boreal Ecosystem Atmosphere Study (BOREAS). *Plant and Soil*.
- Densmore, R.V., Juday, G.P., and Zasada, J.C. 1999. Regeneration alternatives for upland white spruce after burning and logging in interior Alaska. *Canadian Journal of Forest Research*, 29: 413-423.
- Doyle, A.P., and Schimel, J.P. 1998. Dichromate digestion and simultaneous colorimetry of microbial carbon and nitrogen. *Soil Science Society of America Journal*, 62: 937-941.
- Edwards, M.E., Bigelow, N.H., Finney, B.P., and Eisner, W.R. In press. Records of aquatic pollen and sediment properties as indicators of late-Quaternary Alaskan lake levels. *Journal of Paleolimnology*.
- Elias, S., Hamilton, S., Edwards, M., Beget, J., Krumhardt, A., and Lavoie, C. 1999. Late Pleistocene environments of the western Noatak Basin, northwestern Alaska. *Geological Society of America Bulletin*, 111: 769-789.
- Epstein, H.E., Walker, M.D., Chapin, F.S. III, and Starfield, A.M. 2000. A transient, nutrient-based model of arctic plant community response to climatic warming. *Ecological Applications*, 10(3):824-841.
- Eugster, W., Rouse, W.R., Pielke, R., McFadden, J.P., Baldocchi, D.D., Kittel, T.G.F., Chapin, F.S., III, Liston, G., Vidale, P.L., Vaganov, E., and Chambers, S. In press. Land-atmosphere energy exchange in arctic tundra and boreal forest: available data and feedbacks to climate. *Global Change Biology*. 6(Suppl. 1): 84-115.
- Farmer, G.L., Goldfarb, R.J., Lilly, M.R., Bolton, B., Meier, A.L., and Sanzolone, R.F. 2000. The chemical characteristics of groundwater near Fairbanks, Alaska. *Geologic Studies in Alaska by the U.S. Geological Survey, 1998, U.S. Geological Survey Professional Paper 1615*. pp 167-178.
- Fleming, M., Chapin, F.S., III, Cramer, W., Hufford, G., and Serreze, M.C. 2000. Geographic patterns and dynamics of Alaskan climate interpolated from a sparse station record. *Global Change Biology* 6(Suppl. 1): 49-58
- Gregory-Eaves, I., Smol, J.P., Finney, B.P., Lean, D.S., and Edwards, M. In press. Diatom-based transfer functions for inferring past climatic and environmental changes in Alaska. *Arctic, Antarctic and Alpine Research*.
- Gregory-Eaves, I., Smol, J.P., Finney, B.P., Lean, D.S., and Edwards, M.E. In press. Limnological variation in lakes along a north-south transect in Alaska and its relationship to climate. *Archiv für Hydrobiologie*.
- Grogan, P., and Chapin, F.S., III. 1999. Arctic soil respiration: effects of climate and vegetation depend on season. *Ecosystems*, 2: 451-459.
- Gulledge, J., and Schimel J.P. 2000. Controls on soil carbon dioxide and methane fluxes in a variety of taiga forest stands in interior Alaska. *Ecosystems* 3: 269-282
- Gulledge, J., and Schimel, J.P. 1998. Low-concentration kinetics of atmospheric CH<sub>4</sub> oxidation in soil and mechanism of NH<sub>4</sub><sup>+</sup> inhibition. *Applied and Environmental Microbiology*, 64: 4291-4298.
- Gulledge, J., and Schimel, J.P. 1998. Moisture control over atmospheric CH<sub>4</sub> consumption and CO<sub>2</sub> production in physically diverse soils. *Soil Biology & Biochemistry*, 30: 1127-1132. Gulledge, J., Steudler, P.A., and Schimel, J.P. 1998. Effect of CH<sub>4</sub> starvation on atmospheric CH<sub>4</sub> oxidizers in taiga and temperate forest soils. *Soil Biology & Biochemistry*, 30: 1463-1467.
- Harden, J., Trumbore, S.E., Stocks, B., Hirsche, A., Gower, S.T., O'Neill, K.P., and Kasischke, E.S. 2000. The role of fire in the boreal carbon budget. *Global Change Biology* 6(Suppl. 1): 174-184.
- Hastings, F.L., Werner, R.A., Holsten, E.H., and Shea, P.J. In press. Carabid and bark beetles: a review. *Journal of Economic Entomology*.

- Hastings, F.L., Werner, R.A., Shea, P.J., and Holsten, E.H. 1998. Persistence of carbaryl within boreal, temperate and mediterranean ecosystems. *Journal of Economic Entomology*, 91: 665-670.
- Hobbie, S.E., and Chapin, F.S., III. 1998. An experimental test of limits to tree establishment in arctic tundra. *Journal of Ecology*, 86: 449-461.
- Jacoby, G.C., D'Arrigo, R.D., and Juday, G. 1999. Tree-ring indicators of climatic change at northern latitudes. *World Resource Review*, 11: 21-29.
- Julkunen-Tiitto, R., Rousi, J.M., Bryant, J.P., Sorsa, S., Keinanen, M., and Sikanen, H. In press. Chemical diversity of several Betulaceae species: comparisons of phenolics and terpenoids in northern birch stems. *Trees*.
- Kielland, K., and Bryant, J.P. 1998. Moose herbivory in taiga: effects on biogeochemistry and vegetation dynamics in primary succession. *Oikos*, 82: 377-383.
- Kielland, K., and Osborne, T. 1998. Moose browsing on feltleaf willow: optimal foraging in relation to plant morphology and chemistry. *Alces*, 34: 149-155.
- Kielland, K., Barnette, B., and Schell, D. 1998. Intra-seasonal variation in the  $\delta^{15}\text{N}$  signatures of taiga trees and shrubs. *Canadian Journal of Forest Research*, 28: 485-488.
- Kittel, T.G.F., Steffen, W.L., and Chapin, F.S., III. 2000. Global and regional modeling of arctic-boreal vegetation distribution and its sensitivity to altered forcing. *Global Change Biology* 6(Suppl. 1): 1-18.
- Kwok, R., Rignot, E.M., Way, J., Freeman, A., and Holt, J. 1994. Polarization signatures of frozen and thawed forests of varying environmental state. *IEEE Transactions on Geoscience and Remote Sensing*, 32: 371-381.
- MacLean, R.M., Oswood, M.W., Irons, J.G., III., and McDowell, W.H. 1999. The effect of permafrost on stream biogeochemistry: a case study of two streams in the Alaskan (U.S.A.) taiga. *Biogeochemistry*, 47: 239-267.
- Malmstrom, C.M., and Raffa, K.F. 2000. Response of boreal forest to climate change: the role of insect herbivores and plant pathogens. *Global Change Biology*. 6(Suppl. 1): 35-48.
- Mann, D.H., and Plug, L.J. 1999. Vegetation and soil development at an upland taiga site, Alaska. *Ecoscience*, 6: 272-285.
- McCullough, D.G., Werner, R.A., and Neumann, D. 1998. Fire and insects in northern and boreal forest ecosystems of North America. *Annual Review of Entomology*, 43: 107-127.
- McGuire, A.D., and CCMLP. In press. CO<sub>2</sub>, climate and land-use effects on the terrestrial carbon balance, 1920-1992. *Global Geochemical Cycles*.
- McGuire, A.D., Clein, J., Melillo, J.M., Kicklighter, D.W., Meier, R.A., Vörösmarty, S.J., and Serreze, M.C. 2000. Modeling carbon responses of tundra ecosystems to historical and projected climate: the sensitivity of pan-arctic carbon storage to temporal and spatial variation in climate. *Global Change Biology* 6(Suppl. 1): 141-159.
- McGuire, A.D., Melillo, J.M., Randerson, J.T., Parton, W.J., Heimann, M., Meier, R.A., Clein-Curley, J.S., Kicklighter, D.W., and Sauf, W. In press. Modeling the effects of snowpack on heterotrophic respiration across northern temperate and high latitude regions: comparison with measurements of atmospheric carbon dioxide in high latitudes. *Biogeochemistry*.
- McGuire, A.D., Sitch, J.S., Clein, R., Dargaville, G., Esser, J., Foley, M., Heimann, F., Joos, J., Kaplan, D.W., Kicklighter, R.A., Meier, J.M., Melillo, B., Moore III, I.C., Prentice, N., Ramankutty, T., Reichenau, A., Schloss, H., Tian, L.J., Williams, and U. Wittenberg. In press. Carbon balance of the terrestrial biosphere in the twentieth century: Analyses of CO<sub>2</sub>, climate and land-use effects with four process-based ecosystem models. *Global Biogeochemical Cycles*.

- Michalek, J.L., French, N.H.F., Kasischke, E.S., Johnson, R.D., and Colwell, J.E. In press. Using Landsat TM data to estimate carbon release from burned biomass in an Alaskan spruce forest complex. *International Journal of Remote Sensing*.
- Milner, A.M. and M.W. Oswood. 2000. Urbanization gradients in streams of Anchorage, Alaska: a comparison of multivariate and multimetric approaches to classification. *Hydrobiologia* 422/423: 209-223.
- Moore, D.L., Stephenson, S.L., Laursen, G.A., and Woodgate, W.A. 2000. Protostelids from boreal forest and tundra ecosystems in Alaska. *Mycologia*, 92(3): 390-393.
- Muhs, D., Ager, T., and Beget, J. In press. Vegetation and paleoclimate of the last interglacial period, central Alaska. *Quaternary Science Reviews*.
- Naeem, S., Chapin, F.S., III., Costanza, R., Ehrlich, P.R., Golley, F.B., Hooper, D.U., Lawton, J.H., O'Neill, R.V., Mooney, H.A., Sala, O.E., Symstad, A.J., and Tilman, D. 1999. Biodiversity and ecosystem functioning: maintaining natural life support processes. *Issues in Ecology*, 4: 1-12.
- Niemela, P., Chapin, F.S., III., Danell, K., and Bryant, J.P. In press. Animal-mediated responses of boreal forest to climatic change. *Climatic Change*.
- Osterkamp, T.E., and Romanovsky, V.E. 1999. Evidence for warming and thawing of discontinuous permafrost in Alaska. *Permafrost and Periglacial Processes*, 10: 17-37.
- Osterkamp, T. E., L. Viereck, Y. Shur, M. T. Jorgenson, C. H. Racine, A. P. Doyle, and R. D. Boone, Observations of thermokarst in boreal forests in Alaska, Arctic, Antarctic, and Alpine Research, 32: 303-315, 2000.
- Oswood, M.W., J.B. Reynolds, J.G. Irons III, A.M. Milner. 2000. Distributions of freshwater fishes in ecoregions and hydroregions of Alaska. *Journal of the North American Benthological Society* 19:405-418.
- Romanovsky, V. E., and T. E. Osterkamp. 2000. Effects of unfrozen water on heat and mass transport processes in the active layer and permafrost, *Permafrost and Periglacial Processes* 11: 219-239.
- Ruess, R.W., Hendrick, R.L., and Bryant, J.P. 1998. Regulation of fine root dynamics by mammalian browsers in early successional Alaskan taiga forests. *Ecology*, 79: 2706-2720.
- Rupp, T.S., A.M. Starfield, and F.S. Chapin, III. 2000. A frame-based spatially explicit model of subarctic vegetation response to climatic change: comparison with a point model. *Landscape Ecology* 15:383-400.
- Rupp, T.S., F.S. Chapin, III, and A.M. Starfield. In press. Modeling the influence of topographic barriers on treeline advance at the forest-tundra ecotone in northwestern Alaska. *Climatic Change*.
- Rupp, T.S., Chapin, F.S., III, and Starfield, A.M. In press. Response of subarctic vegetation to transient climatic change on the Seward Peninsula in northwest Alaska. *Global Change Biology*.
- Sala, O.E., F.S. Chapin, III, J.J. Armesto, E. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sanwald, L.F. Huenneke, R. Jackson, A. Kinzig, R. Leemans, D. Lodge, H.A. Mooney, M. Oesterheld, N.L. Poff, M.T. Sykes, B.H. Walker, M. Walker, and D.H. Wall. 2000. Global biodiversity scenarios for the year 2100. *Science* 287:1770-1776.
- Schimel, J.P., and Gulledge, J. 1998. Microbial community structure and global trace gases. *Global Change Biology*, 4: 745-758.
- Schimel, J.P., Cates, R.G., and Ruess, R. 1998. The role of balsam poplar secondary chemicals in controlling nutrient dynamics through succession in the Alaskan taiga. *Biogeochemistry*, 42: 221-234.
- Schimel, J.P., Gulledge, J.M., Clein-Curley, J.S., Lindstrom, J.E., and Braddock, J.F. 1999. Moisture effects on microbial activity and community structure in decomposing birch litter in the Alaskan taiga. *Soil Biology & Biochemistry*, 31: 831-838.

- Serreze, M.C., Walsh, J.E., Chapin, F.S., III., Osterkamp, T., Dyrurgerov, M., Romanovsky, V., Oechel, W., Morison, F., Zhang, T., and Barry, R.G. 2000. Observational evidence of recent change in the northern high-latitude environment. *Climatic Change* 46:159-207.
- Suominen, O., Danell, K., and Bryant, J.P. 1999. Indirect effects of mammalian browsers on vegetation and ground-dwelling insects in an Alaskan floodplain. *Ecoscience*, 6: 505-510.
- Uliassi, D.D., Huss-Danell, K., Ruess, R.W., and Doran, K. In press. Biomass allocation and nitrogenase activity in *Alnus tenuifolia*: responses to successional soil type and phosphorus availability. *Ecoscience*.
- Vance, E.D., and Chapin, F.S., III. In press. Substrate-environment interactions: multiple limitations to microbial activity in taiga forest floors. *Biogeochemistry*.
- Verbyla, D. L. and S. H. Boles. 2000. Bias in Land Cover Change Estimates Due To Misregistration.
- Wagener, S.M., and Schimel, J.P. 1998. Stratification of soil ecological processes: a study of the birch forest floor in the Alaskan taiga. *Oikos*, 81: 63-74.
- Wagener, S.M., Oswood, M.W., and Schimel, J.P. 1998. Rivers and soils: parallels in carbon and nutrient processing. *Bioscience*, 48: 104-108.
- Waide, R.B., Willig, M.R., Mittelbach, G., Steiner, C., Gough, L., Dodson, S.I., Juday, G.P., and Parmenter, R. 1999. The relationship between productivity and species richness. *Annual Review of Ecology and Systematics*, 30: 257-300.
- Walker, M.D., Walker, D.A., Welker, J.M., Arft, A.M., Bardsley, T., Brooks, P.D., Fahnestock, J.T., Jones, M.H., Losleben, M., Parsons, A.N., Seastedt, and Turner, P.L. 1999. Long-term experimental manipulation of winter snow regime and summer temperature in arctic and alpine tundra. *Hydrological Processes*, 13:2315-2330
- Werner, R.A. 1994. Forest insect research in boreal forests of Alaska. *Entomology (Trends in Agricultural Science)*, 2: 35-46.
- Werner, R. A. 1996. Forest health in boreal ecosystems of Alaska. *The Forestry Chronicle*, 72: 43-4.
- Werner, R.A. (in press) Effect of ecosystem disturbance on diversity of wood borers and bark beetles (Coleoptera: Buprestidae, Cerambycidae, Scolytidae) in white spruce ecosystems of Alaska. *Environmental Entomology*.
- Wurtz, T.L. 2000. Interactions between white spruce and shrubby alders at three boreal forest sites in Alaska. Gen. Tech. Rep. PNW. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 29 p.
- Yarie, J. 2000a. Boreal forest ecosystem dynamics I: A new spatial model. *Can. J. For. Res.* 30:998-1009.
- Yarie, J. 2000b. Boreal forest ecosystem dynamics II: Application of the model to four vegetation types in interior Alaska. *Can J. For. Res.* 30:1010-1023
- Yarie, J., Viereck, L., Van Cleve, K., and Adams, P. 1998. Flooding and ecosystem dynamics along the Tanana River. *BioScience*, 48: 690-695.
- Zimov, S.A., Davidov, S.P., Zimova, G.M., Davidova, A.I., Chapin, F.S., III., Chapin, M.C., and Reynolds, J.F. 1999. Contribution of disturbance to high-latitude amplification of atmospheric CO<sub>2</sub>. *Science*, 284: 1973-1976.

### Books

- Chapin, F.S., III, Sala, O., and Huber-Sannwald, E. (eds.). In press. Scenarios of future biodiversity. Springer-Verlag. New York.
- Kasischke, E.S., and Stocks, B.J. (eds.). 1999. Fire, climate change and carbon cycling in the boreal forest. Ecological Studies Series, Springer-Verlag. New York. 461 pp.

Lambers, H., Chapin, F.S., III., and Pons, J.L. 1998. Plant physiological ecology. Springer-Verlag. New York. 540 pp.

#### Book Chapters and Conference Proceedings

- Babcock, C., and Juday, G.P. 1998. Wildlife and reindeer. In Implications of global change in the western Arctic. Edited by G. Weller and P. Anderson. Center for Global Change and Arctic System Research, University of Alaska Fairbanks. Fairbanks, AK. Pp. 57-66.
- Berman, M., Juday, G.P., and Burnside, R. In press. Climate change and Alaska's forests: people, problems, and policies. In Implications of global change in Alaska and the Bering Sea region. Edited by G. Weller and P. Anderson. Center for Global Change and Arctic System Research, University of Alaska Fairbanks.
- Bledsoe, C.S., Fahey, T.J., Day, F.P., and Ruess, R.W. 1999. Measurement of static root parameters - biomass, length, and distribution in the soil profile. In Standard soil methods for long-term ecological research. Edited by G.P. Robertson, C.S. Bledsoe and P. Sollins. Oxford University Press. Oxford. Pp. 413-436.
- Bolton, W.R., Hinzman, L., and Yoshikawa, K., 2000. Stream flow studies in a watershed underlain by discontinuous permafrost. In Proceedings AWRA Spring specialty conference, Water Resources in Extreme Environments, edited by Douglas L. Kane, May 1-3, 2000, Anchorage Alaska. pp31-36.
- Boone, R.D., Grigal, D.F., Sollins, P., Ahrens, R.J., and Armstrong, D.E. 1999. Soil sampling, preparation, archiving, and quality control. In Standard soil methods for long-term ecological research. Edited by G.P. Robertson, C.S. Bledsoe, D.C. Coleman and P. Sollins. Oxford University Press. Oxford. Pp. 3-28.
- Chapin, F.S., III., and Danell, K. In press. Scenarios of biodiversity change in the boreal forest. In Scenarios of future biodiversity. Edited by F.S. Chapin III, O. Sala and E. Huber-Sannwald. Springer-Verlag. New York.
- Dargaville, R.J., McGuire, A.D. and Rayner, P. (in press) Estimates of large-scale fluxes in high latitudes from terrestrial biosphere models and an inversion of atmospheric CO<sub>2</sub> measurements. 2000. Proceedings of the International Boreal Forest Research Association Conference: The Role of Boreal Forests and Forestry in the Global Carbon Cycle.
- Douglas, D., Juday, G.P., and Meehan, R. 1998. Arctic tundra. In Implications of global change in Alaska and the Bering Sea region. Edited by G. Weller and P. Anderson. Center for Global Change and Arctic System Research, University of Alaska Fairbanks. Fairbanks, AK. Pp. 51-66.
- Everett, J.T., Fitzharris, B.B., Maxwell, B., and contributors (including A.D. McGuire). 1998. The Arctic and the Antarctic. In The regional impacts of climate change: an assessment of vulnerability. Edited by R.T. Watson, M.C. Zinyowera and R.H. Moss. Cambridge University Press. New York. Pp. 85-103.
- Eviner, V.T., F.S. Chapin, III and C. Vaughn. 2000. Nutrient manipulations in terrestrial ecosystems. Pages 291-307 In: O.E. Sala, R.B. Jackson, H.A. Mooney, and R.W. Howarth, Eds. Methods in Ecosystem Science. Springer-Verlag, New York.
- Fahey, T.J., Bledsoe, C.S., Day, F.P., Ruess, R.W., and Smucker, A.J.M. 1999. Fine root production and demography. In Standard soil methods for long-term ecological research. Edited by G.P. Robertson, C.S. Bledsoe, D.C. Coleman and P. Sollins. Oxford University Press. Oxford. Pp. 437-455.
- French, N.H.F., Kasischke, E.S., Stocks, B.J., Mudd, J.P., Lee, B.S., and Martell, D.L. 1999. Carbon released during fires in North American boreal forests. In Fire, climate change and carbon cycling in the boreal forest. Edited by E.S. Kasischke

- and B.J. Stocks. Ecological Studies Series, Springer-Verlag. New York. Pp. 377-388.
- Grigal, D.F., Bell, J.C., Ahrens, R.J., Boone, R.D., Kelly, E.F., Monger, H.C., and Sollins, P. 1999. Site and landscape characterization for ecological studies. In Standard soil methods for long-term ecological research. Edited by G.P. Robertson, C.S. Bledsoe, D.C. Coleman and P. Sollins. Oxford University Press. Oxford. Pp. 29-52.
- Holland, E.A., Robertson, G.P., Greenberg, J., Groffman, P.M., Boone, R.D., and Gosz, J.R. 1999. Soil CO<sub>2</sub>, N<sub>2</sub>O, and CH<sub>4</sub> exchange. In Standard soil methods for long-term ecological research. Edited by G.P. Robertson, C.S. Bledsoe, D.C. Coleman and P. Sollins. Oxford University Press. Oxford. Pp. 29-52.
- Juday, G.P., Barber, V., Berg, E., and Valentine, D. 1999. Recent dynamics of white spruce treeline forests across Alaska in relation to climate. In Sustainable development in northern timberline forests. Proceedings of the Timberline Workshop. Research Paper 734. Edited by S. Kankaanpaa, T. Tasanen and M. Sutinen. The Finnish Forest Research Institute, Ministry of the Environment. Finland. Pp. 165-187.
- Juday, G.P., Cochran, V., Henning, S., McDowell, E., Rethford, S., Rice, W., and Sparrow, S. 1998. Human land use and management. In Implications of global change in Alaska and the Bering Sea region. Edited by G. Weller and P. Anderson. Center for Global Change and Arctic System Research, University of Alaska Fairbanks. Fairbanks, AK. Pp. 67-74.
- Juday, G.P., Ott, R.A., Valentine, D.W., and Barber, V.A. 1998. Forests, climate stress, insects, and fire. In Implications of global change in Alaska and the Bering Sea region. Edited by G. Weller and P. Anderson. Center for Global Change and Arctic System Research, University of Alaska Fairbanks, Fairbanks, AK. Pp. 23-49.
- Kasischke, E.S., Bourgeau-Chavez, L.L., O'Neill, K.P., and French, N.H.F. In press. Indirect and long-term effects of fire on the boreal forest carbon budget. In Biomass burning and its interactions with the climate system. Edited by M. Beniston, J.L. Innes and M.M. Verstraete. Cambridge University Press.
- Kasischke, E.S., French, N.H.F., and Bourgeau-Chavez, L.L. 1999. Using satellite data to monitor fire-related processes in the boreal forests. In Fire, climate change and carbon cycling in the boreal forest. Edited by E.S. Kasischke and B.J. Stocks. Ecological Studies Series, Springer-Verlag, New York. Pp. 406-422.
- Kasischke, E.S., O'Neill, K.P., French, N.H.F., Richter, D.D., Bourgeau-Chavez, L.L., and Harrell, P.H. 1999. Influence of fire on long-term patterns of forest succession in Alaskan boreal forests. In Fire, climate change and carbon cycling in the boreal forest. Edited by E.S. Kasischke and B.J. Stocks. Ecological Studies Series, Springer-Verlag, New York. Pp. 214-238.
- Kasischke, E.S., O'Neill, K.P., French, N.F., and Bourgeau-Chavez, L.L. 1999. Patterns of biomass burning in Alaskan boreal forests. In Fire, climate change and carbon cycling in the boreal forest. Edited by E.S. Kasischke and B.J. Stocks. Ecological Studies Series, Springer-Verlag. New York. Pp. 173-196.
- Kasischke, E.S., Stocks, B.J., O'Neill, K.P., French, N.F., and Bourgeau-Chavez, L.L. In press. Direct effects of fire on the boreal forest carbon budget. In Biomass burning and its inter-relationships with the climate system. Edited by J.L. Innes, M.M. Verstraete and M. Beniston. Kluwer Academic Publishers. Dordrecht, The Netherlands.
- Kielland, K. In press. Short-circuiting the nitrogen cycle: ecophysiological strategies of nitrogen uptake in plants from marginal environments. In New concepts in plant nutrient acquisition. Edited by N. Ae, K. Okada and J. Arehara. Springer-Verlag. Berlin.

- Mooney, H.A., Canadell, J., Chapin, F.S., III., Ehleringer, J., Körner, C.H., McMurtrie, R., Parton, W.J., Pitelka, L., and Schulze, E.-D. 1999. Ecosystem physiology responses to global change. In *The terrestrial biosphere and global change: implications for natural and managed ecosystems*. Edited by B. Walker, W. Steffen, J. Canadell and J. Ingram. Cambridge University Press. Cambridge, UK. Pp. 141-189.
- Motyka, R., and Beget, J. 1998. Recent retreat of LeConte Glacier and associated calving and iceberg hazards. State of Alaska, Division of Geology and Geophysical Surveys Report of Investigations 98-15. 9 pp.
- Myrold, D.D., Ruess, R.W., and Klug, M. 1999. Dinitrogen fixation. In *Standard soil methods for long-term ecological research*. Edited by G.P. Robertson, C.S. Bledsoe, D.C. Coleman and P. Sollins. Oxford University Press. New York, NY. Pp. 241-257.
- Ott, R.A., G.P. Juday, and T.E. Garvey. 1999. Conducting a landscape-level wind risk assessment on northeast Chichagof Island, southeast Alaska, and its potential use for forest management. In *Proceedings of the Annual Meeting of the Society of American Foresters*. 20-24 September, 1998. Society of American Foresters. Pp. 202-210.
- Paetzold, R.F., Hinkel, K.M., Nelson, F.E., Osterkamp, T.E., Ping, C.L., and V.E Romanovsky. 2000. Temperature and Thermal Properties of Alaska Soils. *Global Climate Change and Cold Regions Ecosystems*. In *Advances in Soil Science*. Edited by Lal.R., Kimble J.M., and B.A. Stewart. CRC Press LLC. Boca Raton, Florida
- Paul, E.A., Harris, D., Klug, M., and Ruess, R.W. 1999. The determination of microbial biomass. In *Standard soil methods for long-term ecological research*. Edited by G.P. Robertson, C.S. Bledsoe, D.C. Coleman and P. Sollins. Oxford University Press. New York, NY. Pp. 291-317.
- Poff, N.L., Angermeier, P.L., Cooper, S., Lake, P.S., Fausch, K.D., Winemiller, K., Mertes, L., Rahel, F., Oswood, M., and Reynolds, J. In press. Climate change and stream fish diversity. In *Scenarios of future biodiversity*. Edited by F.S. Chapin, O. Sala and E. Huber-Sannwald. Springer-Verlag, New York.
- Romanovsky, V. E., and Osterkamp, T. E. In press. Permafrost: Changes and Impacts, in: R. R. Paepe "Permafrost Response on Economic Development, Environmental Security and Natural Resource Potential", NATO-Advanced Research Workshop.
- Sala, O.E., Chapin, F.S., III., Gardner, R.H., Lauenroth, W.K., Mooney, H.A., and Ramakrishnan, P.S. 1999. Global change, biodiversity and ecological complexity. In *The terrestrial biosphere and global change: implications for natural and managed ecosystems*. Edited by B. Walker, W. Steffen, J. Canadell and J. Ingram. Cambridge University Press. Cambridge, UK. Pp. 304-328.
- Schulze, E.-D., Scholes, R.J., Ehleringer, J.R., Hunt, L.A., Canadell, J., Chapin, F.S., III., and Steffen, W.L. 1999. The study of ecosystems in the context of global change. In *The terrestrial biosphere and global change: implications for natural and managed ecosystems*. Edited by B. Walker, W. Steffen, J. Canadell and J. Ingram. Cambridge University Press. Cambridge. Pp. 19-44.
- Slaughter, C.K., Spaeth, K.E., Viereck, L.A., and Hanson C.L. 1998. Watershed research programs: opportunities for long-term biodiversity monitoring and research. In *Forest Biodiversity Research, Monitoring and Modeling*. Man and the Biosphere Series, Vol. 20. Smithsonian institution/Man and the Biosphere Biodiversity Program. Edited by F. Dallmeier and J.A. Comiskey. Smithsonian Institution and UNESCO, Parthenon, New York. Pp. 335-354..
- Wurtz, T.L. In press. Interactions between white spruce and shrubby alders at three boreal forest sites in Alaska. Gen. Tech. Rep. PNW. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

### Theses and Dissertations

- Adams, P.C. 1999. The dynamics of white spruce populations on a boreal river floodplain. Ph.D. Dissertation. Duke University. Durham, NC. 178 pp.
- Billings, S.A. 1998. Effects of rainfall exclusion on soil carbon gases and water relations in two boreal forest ecosystems. Ph.D. Dissertation. Duke University, Durham, NC. 117 pp.
- Rupp, T.S. 1998. Boreal forest regeneration dynamics: modeling early forest establishment patterns in interior Alaska. Ph.D. Dissertation. University of Alaska Fairbanks. Fairbanks, AK. 245 pp.
- Uliassi, D.D. 1998. The regulation of symbiotic nitrogen fixation by thinleaf alder in primary successional forests of the Tanana River floodplain. M.S. Thesis. University of Alaska Fairbanks. Fairbanks, AK. 114 pp.

### Other Publications

- Juday, G.P. 1998. Alaska research natural areas: 4. Big Windy Hot Springs. Agricultural and Forestry Experiment Station Miscellaneous Publication 98-1. University of Alaska Fairbanks. 47 pp.
- Juday, G.P. 1998. Climate change and its ecological effects in interior Alaska. In Managing for forest condition in interior Alaska: what are our options? Technical Workshop. 9-10 April, 1998. Alaska Cooperative Extension Service. Fairbanks, AK. Pp. 22-23.
- Juday, G.P. 1998. Spruce beetles, budworms, and climate warming. Global Glimpses (Center for Global Change and Arctic System Research, University of Alaska Fairbanks), 6 (1): 1-2.
- Juday, Glenn Patrick. 2000. Climate change and the growth of white spruce near Anchorage, Alaska. *Agroborealis*. 32(1): 10-14

### Papers Submitted

- Potter, C., Amthor, J.S., King, A.W., Nikolov, N.T., Chen, J.M., Liu, J., Frokling, S.E., Grant, R.F., Wang, S., Kimball, J., Running, S., McGuire, A.D., and Clein, J.S. (submitted) Comparison of boreal ecosystem model sensitivity to variability in climate and forest site parameters. *Journal of Geophysical Research - Atmospheres*.
- Bryant, D.M., Rastetter, E.B., Nadelhoffer, K.J., Walker, M.D., and Laundre, J.L. Submitted. Litter decomposition in the tundra biome: A comparison of the Arctic and Alpine LIDET data.
- Burton, A.J., K.S. Pregitzer, R.W. Ruess, R.L. Hendrick, and M.F. Allen. Submitted. Fine root respiration rates in North American forests: effects of nitrogen concentration and temperature across biomes. *Oecologia*.
- Dissing, D. and D. L. Verbyla. Submitted. Landscape interactions with thunderstorms in Interior Alaska. *Landscape Ecology*.
- Epstein, H.E. Chapin F.S. III, Walker, M.D., and Starfield, A.M. Submitted. Simulating tundra vegetation at varying levels of aggregation: An analysis of functional groupings. *Ecology*
- Kielland, K., Osborne, T., and Yokel, D. Submitted. Moose-willow relationships along three major river systems in Alaska. *Journal of Range Management*.
- Pregitzer, K.S., J.L. DeForest, A.J. Burton, M.F. Allen, R.W. Ruess, and R.L. Hendrick. Submitted. Root length, diameter, specific root length and nitrogen concentration of nine tree species across four North American biomes. *Ecology*.

- Rees, D.C., and Juday, G.P. Submitted. Plant species diversity and forest structure on logged and burned sites in central Alaska. *Forest Ecology and Management*.
- Roininen, H., Price, P., and Bryant, J.P. Submitted. Effect of browsing by moose on sawfly abundance of willow. *Oikos*.
- Romanovsky, V. E., Osterkamp, T. E., Sazonova, T. S., Shender, N. I. and V. T. Balobaev. Submitted. Permafrost Temperature Dynamics Along the East Siberian Transect and an Alaskan Transect, Proceedings of the International Workshop on Global Change: Connection to the Arctic, Sendai, Japan, 18-25 August.
- Romanovsky, V. E. and Osterkamp, T. E. Submitted. Permafrost Monitoring System in Alaska: Structure and Results (in Russian), *Earth Cryosphere*.
- Rupp, T.S., Starfield, A.M., Chapin F.S. III, and Duffy P. 2000. Submitted. Modeling the impact of black spruce on the fire regime of Alaskan boreal forest. *Canadian Journal of Forest Research*.
- Smidt, S., and Oswood, M.W. Submitted. Landscape patterns and stream reaches in the Alaskan taiga forest: potential roles of permafrost in differentiating macroinvertebrate communities. *Hydrobiologia*.
- Suominen, O., Danell, K., and Bryant, J.P. Submitted. Effects of winter browsing by moose and snowshoe hares on the abundance of ground-living insects. *Ecology*.
- Uliassi, D.D., and Ruess, R.W. Submitted. The regulation of symbiotic nitrogen fixation by thinleaf alder in primary successional forests of the Tanana River floodplain. *Ecology*.
- Werner, R.A., and Holsten, E.H. (submitted.) Use of semiochemicals of secondary bark beetles to disrupt spruce beetle (Coleoptera: Scolytidae) attraction and survival in Alaska. *Environmental Entomology*.
- Wurtz, T. L. and J.C. Zasada. Submitted. An alternative to clearcutting in the boreal forest: a twenty-seven-year trial of shelterwood harvesting in Alaska. *Can. J. for. Res.*
- Yarie, J. and S. Billings. Submitted. Carbon balance of the taiga forest within Alaska. *Forest Ecology and Management*.
- Zhuang, Q., Romanovsky, V.E., and McGuire, A.D. submitted. Incorporation of a permafrost model into a large-scale ecosystem model: Evaluation of temporal and spatial scaling issues in simulating soil thermal dynamics. *J. Geophys. Res. (Atmospheres)*.