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Regional Consequences of Changing Climate-Disturbance Interactions for the Resilience of Alaska's Boreal Forest

Project Summary

The Alaskan boreal forest has remained highly resilient to climate fluctuations since black spruce spread to dominate the region approximately 6,000 years ago; however, evidence is mounting that rapid climate change over the past century has altered the interrelationships among physical, biological and social drivers to influence the regional system. BNZ LTER research has identified key feedbacks that maintain resilience within boreal forests. Climate-driven changes in disturbance regimes have the potential to disrupt these feedbacks and result in regime shifts in successional pathways and landscape structure and function throughout interior Alaska. Changes in key sources of ecological resilience may lead to threshold responses of important variables and processes and thus change landscape structure and heterogeneity. These changes also have important consequences for ecosystem services to Alaskan Native communities, which are particularly vulnerable to the combination of climatic, ecological, and social-economic change given their high cost of living and reliance on the land for food. The **intellectual merit** of the proposed research derives from our program **to *understand the interactive effects of changing climate and disturbance regimes on the Alaska boreal forest, and study associated consequences for regional feedbacks to the climate system, and sustainability of subsistence Alaskan communities.***

Our research program focuses on social-ecological resilience and response to change by integrating four components. (1) Studying past and current **direct effects of climate change** on ecosystems and key disturbance regimes (fire, permafrost thaw, insect/pathogen outbreaks) at local and regional scales; (2) understanding mechanisms and consequences for how **climate-disturbance interactions** drive changes in ecosystems and landscape structure and heterogeneity; (3) modeling the effects of interactions among changes in climate, ecosystem structure and function, and disturbance regimes on **regional ecosystem dynamics and climate feedbacks** (forest-atmosphere exchanges of trace gases, water, and energy); and (4) studying how climate variability and change are affecting the **coupled social-ecological dynamics** of rural Alaskan villages by understanding how changes in ecosystem services are affecting community resilience and helping to identify opportunities for adaptation and/or transformation of community practices.

The research design combines long-term observations, long-term experiments, dendrochronological studies, and on-going and new process studies to understand the ecological feedbacks contributing to resilience and the underlying mechanisms for vegetation and landscape change in floodplains, uplands, wetlands and boreal (sub-arctic) tundra. Plot-level studies are extended to larger spatial scales (watersheds, interior Alaska, pan-boreal region) in a hierarchical research design using extensive measurements, remote sensing and modeling. Temporal scales of research span hours (weather), years (growth, population dynamics), decades (monitoring, experiments, and stand-age reconstructions), and centuries (vegetation and climate reconstructions). We establish a new network of long-term BNZ LTER research sites to regionalize our research on resilience and mechanisms of ecosystem responses to changes in climate and disturbance regimes in black spruce forests.

Broader impacts include our Schoolyard LTER program, which is actively involved in environmental science training of K-12 students and educators throughout the state of Alaska, and participates in a program to bring rural Alaskan students to Fairbanks during the summer to be mentored by BNZ LTER scientists. We also actively engage undergraduates and graduate students in research and K-12 education, and are involved with a number of Network-wide educational programs. To make information available and useful to the broader community, we interact with local artists and scientists, collaborate closely with numerous state and federal agencies and Native organizations through joint research programs, workshops and meetings, and convene the BNZ LTER Community Resilience Working Group composed of village leaders who meet annually to review BNZ LTER research findings and discuss opportunities for community adaptation and transformation. Involvement in LTER cross-site comparisons enables us to study and understand the boreal forest in a broader social-ecological context. Information management emphasizes secure archival of data, promotion of its use in synthesis, and development of web-based databases to facilitate access to and use of data by the scientific community.

Section 1: Prior Results

High-latitude amplification of 20th century global warming has caused Alaska's boreal forest to warm twice as rapidly as the global average (77, 101). Mean annual air temperature in interior Alaska increased by 1.3˚C during the past 50 years (73, 191) and is projected to increase by an additional 3-7˚C by the end of the 21st century (http://www.snap.uaf.edu). Precipitation has increased by only 1.4 mm decade^{-1} over this same period (78). Its projected continued increase will likely be insufficient to offset increased summer evapotranspiration, leading to potentially drier soils and lower lake levels.

In response to a gradual Holocene cooling and moistening of climate, black spruce (*Picea mariana)* and its associated fire regime assumed regional dominance in Interior Alaska 5,000-7,000 years ago, producing a landscape mosaic similar to that of today (54, 82, 128). This boreal system has persisted relatively unchanged within the detection capabilities of paleoecological indicators since that time, despite substantial climatic fluctuations such as the Medieval Warm Period and Little Ice Age (75, 84, 202). The boreal forest has thus exhibited substantial resilience to past changes in climate. However, warming since the 1950s appears to be unprecedented in at least the last 2000 years (9, 112, 160). In the 6 years of our most recent LTER grant cycle we have experienced the largest fire event (109) and second largest flood on record and unprecedented outbreaks of forest insects (213, 222) and pathogens (179), providing opportunities to study both gradual change and abrupt shocks to the system. This summary of prior results builds on four recent synthesis efforts of the Bonanza Creek (BNZ) LTER: the publication of our LTER synthesis volume (36), a circum-arctic analysis of climate-disturbance interactions in the boreal forest (139), a targeted synthesis based on concerted quality checking and analysis of BNZ long-term datasets (35), and the BNZ contribution to the LTER-Network EcoTrends project. Based on these syntheses, we conclude that the Alaskan boreal system remains remarkably resilient but appears to be undergoing changes in ecosystem and landscape structure, feedbacks, and interactions that, with continued warming, will likely cause reorganization of boreal ecosystems or potentially transformation to a substantially different system, potentially within the timescale of LTER research (31).

BNZ has developed a resilience framework with which to assess both gradual and abrupt ecosystem changes (Fig. 1) (29, 34). We define resilience as the capacity of the system to sustain its fundamental function, structure, and feedbacks when confronted with perturbations such as those resulting from unprecedented warming (29, 65, 215). Resilience depends on the diversity of options available, the ecological and social capacity to adapt to change, and the human capacity to adjust governance to implement new solutions. The boreal forest has properties that convey both *specific resilience* to particular perturbations (e.g., semi-serotinous cones of black spruce that disperse seeds after fire) (91) and *general resilience* (e.g., a diversity of species, successional trajectories, and patch dynamics that permit flexible response to a wide variety of expected and unforeseen perturbations) (32). If the resilience of the system is exceeded, it may transform to some new state that has different system properties, that is sustained by a different set of feedbacks, and is resilient within this new domain of attraction. The balance between persistence of a system (its resilience) and its potential for transformation often depends on the negative (stabilizing) feedbacks that tend to maintain the system in its current state and positive (amplifying) feedbacks that tend to push the system toward some new state (29, 32). We hypothesize that the boreal forest, like all ecosystems, has a suite of stabilizing feedbacks associated with competition, trophic dynamics, and successional cycles that sustain its characteristics over time. We further hypothesize that certain climate-driven changes could initiate amplifying feedbacks that might transform the boreal forest to a new state (Fig. 1). Triggers for change might include: 1) changes in soil moisture and hydrology associated with loss of permafrost, increased growing-season length, and seasonal timing of soil moisture recharge, 2) changes in successional trajectory and biogeochemistry associated with changes in fire, flooding, and insect/pathogen outbreaks, 3) changes in abundance of keystone or dominant species, including white spruce, alder, *Sphagnum* mosses, and snowshoe hares, and 4) changes in human use of landscapes.

Climate Sensitivity

Climate sensitivity of uplands and well-drained sites: In contrast to the continuous permafrost zone of the Arctic, changes in the discontinuous permafrost zone of the boreal forest are driven primarily by *changes in ecosystems* rather than by *climatic change* (100). In Interior Alaska, for example, changes in air temperature have had less effect on permafrost temperature than do changes in the insulative properties of snow, vegetation, and the surface organic layer (Fig. 2). Consequently, topographic and successional variations in these ecosystem properties lead to a spectrum of permafrost responses to climate warming (100). In north-facing uplands, where there is no impoundment of surface water, gradual warming of permafrost has not greatly altered permafrost integrity except through occasional gully formation.

Upland hydrology has also been relatively resilient to Alaska's long-term warming trend (99). Although there is generally less discharge in warm than in cool years, presumably due to greater evapotranspiration (121), there has been no detectable temporal trend in base flow, total summer discharge or nutrient loss (99, 163). This resilience of the hydrologic regime to direct effects of climate warming contrast strikingly with indirect effects mediated by wildfire and thermokarst effects on permafrost extent, as discussed later.

Earlier snowmelt and later freezeup in interior Alaska (56, 101) have lengthened the growing season, causing trees to leaf out earlier in spring (171). Earlier spring leaf-out increases both photosynthesis and ecosystem respiration and in some systems might increase carbon sequestration (169, 220). However, the functional consequences of longer warmer growing seasons for water, carbon, and nutrient balance of Alaskan boreal ecosystems vary with soil moisture (136) and are important research topics for the next phase of the BNZ LTER.

Extensive fertilization and moisture exclusion studies at BNZ show that moisture is now the primary factor that limits production of Alaskan boreal trees (230, 231). Responses to increased nutrient availability occur primarily early in the season when soils are cold, in cool moist sites, or in wet years. These recent findings of strong drought effects contrast with earlier research, conducted when climate was cooler, which showed widespread nutrient limitation of forest production at our study sites (208, 209).

Consistent with the inference that moisture is now the primary limit on NPP in the boreal forest, most tree species in interior Alaska exhibit negative growth responses to warming (101, 127, 141), a pattern that is consistent with declines since 1990 in greenness indices measured by satellites (69, 210). Reductions in tree growth have been examined most thoroughly in white spruce, the late-successional tree that dominates warm south-facing uplands and lowland floodplain forests. Negative responses of growth to temperature predominate over positive responses in this species (Fig. 3) (101, 141). White spruce is most negatively affected by warming in warm regions and in floodplain landscape positions where river levels are dropping. Even in cool environments such as treeline, however, trees that responded positively to warming prior to 1950 have begun to show a pattern of reduced growth in warm years (126, 227).

Climate-induced changes in NPP may interact with disturbances to reduce the resilience of upland white spruce forests. Although this topic will be one research focus in the next phase of the BNZ LTER, preliminary evidence suggests that disturbance may induce rapid switches in community composition. On the Kenai Peninsula in southern Alaska, extensive insect-caused stand-level mortality of white/Sitka spruce hybrids led to dense growth of the grass *Calamagrostis canadensis* and very poor spruce regeneration, perhaps initiating a switch from forest to grassland or spruce parkland (11). Similar switches in community composition have followed fires elsewhere in the boreal forest. In interior Alaska, upland white spruce has dispersed into adjacent black spruce habitat after fire, producing seedling densities sufficient to generate fully stocked white spruce stands (228). Together these studies suggest a low stand-level resilience of white spruce and perhaps other forest types, but the possibility of landscape-level resilience, if upland species shift into landscape positions that are currently dominated by black spruce. This landscape reorganization might occur extensively (96, 127, 183), if wildland fire continues to increase in extent and severity in upland black spruce forests (108, 110).

Climate sensitivity of lowlands and poorly drained sites: In some poorly drained lowlands, permafrost shows low resilience to climate warming. Here thawing of ice-rich permafrost, much of it having formed during the Little Ice Age, causes surface subsidence and conversion of forests to ponds or wetlands that absorb more radiation due to the low albedo (short-wave reflectance) of the wet surface, thereby accelerating the rates of thaw and landscape change (100, 187). Large carbon stores that were previously stored in permafrost are now being released by respiration on land (186, 189, 242) (Fig. 4) and by methane flux from newly formed ponds and wetlands (217-219, 223, 239) (Fig. 5).

In lowlands underlain by gravel, high-ice permafrost is less common, and climate warming leads to drying of lakes due to increased evapotranspiration and, in some situations, loss of permafrost and internal drainage (100, 170) (Fig. 6). Willows, which colonize drained lake basins, have high rates of evapotranspiration, leading to further drying. Lake drainage and wetland drying is more widespread than paludification across interior Alaska (170).

In many peatlands and black spruce forests, the most widespread forest type in interior Alaska (25), permafrost has been relatively resilient. In these systems, water table depth and plant species composition strongly influence biogeochemical dynamics. *Sphagnum* and other mosses are keystone boreal taxa that account for 22 and 42% of production in uplands and wetlands, respectively (204). They have tended to increase in abundance in some late-successional stands, perhaps in response to insect-induced canopy reduction (80, 204). The effective thermal insulation and low litter quality of mosses, especially *Sphagnum*, lead to cold, permafrost-dominated, nutrient-poor soils that constrain rates of decomposition (212, 223, 224), nutrient cycling (16, 17, 172), and therefore forest productivity (80, 204). These conditions lead to carbon sequestration (27, 81, 164), and variable methane flux depending on soil moisture (225, 239). Despite slow rates of overall carbon and nitrogen cycling, small pools of dissolved organic nitrogen (DON) cycle rapidly (Fig. 7), with rates that are controlled by root/mycorrhizal turnover (175, 177, 178, 180) and competition for DON between plants (and their mycorrhizal fungi) and decomposers (118, 119, 133-135, 221). BNZ researchers have contributed substantially to new perspectives on terrestrial nitrogen cycling that recognize the central roles of root activity and turnover, dissolved organic nitrogen, and plant-microbial competition (41, 113, 134, 135, 177, 185) (Fig. 8). The stabilizing (negative) biogeochemical feedbacks associated with cold wet soils contribute to the resilience of black spruce forests and therefore to the stability of permafrost.

As in most forested ecosystems, Alaskan microbial communities are dominated by fungi, especially by ecto- and ericoid mycorrhizal fungi (68, 199-201). Fungal diversity is at least 10-fold greater than plant diversity in the same sites. Fungal community composition is determined primarily by forest type, soil horizon, and time of year but does not differ among years. These observations suggest extreme fungal specialization to ecosystem structure and seasonality but low sensitivity to interannual variation in climate. We therefore hypothesize that changes in microbial communities and biogeochemical processes will be more sensitive to climatically driven changes in disturbance and vegetation than to the direct effects of climate warming (201, 214).

Climate sensitivity of floodplains: In river floodplains, successional pathways have changed in ways that might have important functional consequences. Thinleaf alder (*Alnus incana* subsp*. tenuifolia*) is a boreal keystone species that expanded in both old and young successional stands along the Tanana River during the 1990s (80, 154). The alder expansion in older stands may reflect improved light availability associated with canopy reduction of white spruce caused by insect outbreaks (response to warmer summers) and ice storms (warmer winters) and of poplar by expanding beaver populations (unknown cause). Increased seed input from alder expansion in mature sites might explain recent increases in alder recruitment in early successional sites. In addition, moose, which have increased in abundance due to predator control, browse heavily on willows, releasing early successional alder recruits (Fig. 9) and invasive plants from competition. Modeling of the functional responses of these interactions between plant competition and herbivory (64) suggests that climate warming and predator control are facilitating invasion of exotic nitrogen fixers (229) and reducing carrying capacity for moose (reduced forage biomass and palatability) (168). These changes indirectly reduce recruitment of white spruce (4). Although the data record is too short to assess long-term persistence of these trends, the patterns suggest that forest resilience in floodplains depends on stand renewal through historically important successional pathways after river disturbance as well as the development of novel successional pathways associated with warmer drier conditions. The relative frequency of historical and novel successional pathways (80, 123) will likely depend on changes in climate, herbivory by moose (a function of predator control and wildfire extent) (116), and alder canker, an expanding forest pathogen that reduces alder abundance and its rates of nitrogen fixation and seed production (179). The reduction in alder growth and N fixation by alder canker is important because of alder's keystone role in N accumulation during floodplain succession (2, 3, 174, 206). Alder canker is most widespread in dry sites and dry years, suggesting a climate link to its spread (154, 179). Green alder in the uplands also interacts with drought-mediated diseases (146), with important implications for post-fire nitrogen economy (3, 143, 144).

In Alaskan floodplains and riparian systems hyporheic flux is more important than we previously recognized. It accounts for more of the nitrogen supply to riparian plants than does mineralization of litter nitrogen (46), so climatically sensitive hydrologic changes might affect terrestrial as well as stream biogeochemistry (99, 124, 156).

In summary, our recent research indicates a high sensitivity of the Alaskan boreal forest to changes in moisture availability and to new species interactions (e.g., with insects and pathogens) that are emerging. This suggests that controls over boreal forest dynamics are shifting from temperature and nutrient limitation, which were well documented in the 1970s and 1980s (208, 209), to more frequent limitation by drought.

Landscape consequences and societal implications

Annual area burned in interior Alaska has doubled in the last decade compared to any decade of the previous 40 years (52, 53, 110, 182) (Fig. 10), a pattern that is widespread in boreal forests (195). Warm summers allow fires to continue burning in late summer, when soils are deeply thawed, have lower soil moisture, and therefore burn more deeply (104, 106, 107, 150, 157, 190, 210), creating a radically different soil environment for seedling establishment (55, 72, 97, 157, 194). These severe fires have broken the legacy lock of black spruce regeneration mediated by biogeochemical feedbacks (thermal insulation by mosses, presence of permafrost, moist soils, and low fire severity) and life-history feedbacks (high availability of black spruce seeds from on-site semi-serotinous cones and effective establishment on organic seedbeds) (91, 96). Instead, the recent increase in mineral soil seedbeds (89, 93, 107) and reduction in fire interval (93) have generated new successional trajectories dominated by deciduous tree seedlings (89-91, 95, 96) (Fig. 11). In extremely dry sites no tree recruitment may occur (91, 95, 106).

These observations suggest potential shifts in the relative abundance of forest types that currently dominate the Alaskan boreal forest: a decline in abundance of black spruce, which has dominated the lowland landscape and north-facing slopes for the last 6,000 years, a potential increase of deciduous forests in former black spruce habitat, and a conversion to grass or shrublands on dry sites (91, 95). Deciduous forests, until now, have been largely restricted to south-facing uplands and floodplain corridors and have acted as a stabilizing feedback to fire probability and spread because of their high leaf moisture content and low flammability. As climate warms, however, vegetation effects on flammability decline, weakening this stabilizing feedback, so the areal extent of fire is projected to continue increasing with climate warming despite the shift to deciduous vegetation (110). Hardwoods accumulate less organic soil than spruce ecosystems (131, 211), so increased hardwood dominance might reduce carbon sequestration at landscape scales.

Historically, the high latent heat content of ice-rich permafrost enabled permafrost to persist after fire until moss-dominated black spruce communities fostered permafrost recovery (100). With a switch to deciduous-dominated vegetation, the thick moss and organic layers are unlikely to rebuild, and permafrost will probably continue to degrade (91, 100, 204). We hypothesize that declines in stand-level resilience in both uplands (due to climatic sensitivity to drought) and lowlands (due to changes in successional feedbacks) convey substantial resilience at the landscape-to-regional scale as a result of potential redistribution of stand types across the landscape. Long-term observations are required to test this hypothesis.

Landscape changes in the boreal forest alter its role in the global climate system. The most dramatic change is earlier snowmelt, which amplifies climate warming as a result of reduced albedo (Fig. 12) (56-58). This is slightly offset by an increase in area burned, which increases albedo in winter (less forest cover to obscure the snow) (1, 125, 166) and in summer (shift to a higher-albedo deciduous forest trajectory) (28, 38, 57, 58). Changes in trace gas (mainly CO_2 and CH_4) feedbacks from the boreal forest are less clear. Greater areal extent and depth of burning and insect outbreaks reduce carbon sequestration (7, 8, 104, 136, 137, 188), but the consequences of the hydrologic reorganization of landscapes are more complex. Sites that are drying generally show reduced rates of carbon, nitrogen and water cycling, with greater declines in GPP than in ecosystem respiration (and therefore a decline in carbon sequestration) (103-105), and sites that are getting wetter show the opposite trends. Methane efflux also declines with drier conditions (204, 205, 239). As ecosystems change in response to permafrost degradation or altered post-fire trajectory, however, the associated changes in vegetation and environment interact to modify ecosystem carbon and nitrogen balance in ways that we are only beginning to understand (147, 158, 187, 188, 226) and incorporate into landscape and regional models (61, 136, 233, 234, 240, 241).

Fire also alters landscape linkages by increasing stream nitrate (Fig. 13) and reducing dissolved organic carbon (13, 162). Streams in the zone of discontinuous permafrost in Interior Alaska have extremely high stream nitrate concentrations, comparable to areas in the NE US that are heavily impacted by acid rain (98). These streams in the boreal zone of discontinuous permafrost also have higher stream nitrate concentrations than areas to the north (continuous permafrost) or south (no permafrost), suggesting that recent warming and deterioration of permafrost may substantially alter stream biogeochemistry (5, 98).

Observed and projected changes in environment and vegetation will influence animal responses to climate warming, as already discussed for insect outbreaks. In general, small mammals such as microtine rodents are more sensitive to interannual variations in weather than are large mammals such as moose and caribou, which respond more strongly to variations in food supply and predation (168). Snowshoe hares are quite sensitive to all of these factors (120) (Fig. 14). Snow depth, rain-on-snow events, floods, and other climate-related events are projected to become more variable (88) and will exert additional effects. Habitat changes that result from warming-induced increases in floods, insect outbreaks, and wildfires could also exert strong effects on mammal distributions and their habitat (21, 22, 132). In general we hypothesize that most mammalian communities will show low resilience, with some species declining in abundance (e.g., lichen-dependent caribou) (183), others increasing (e.g., fire-dependent moose and snowshoe hares) (132), and others changing in species composition and distribution (e.g., microtines that are sensitive to extreme events but some of which are favored by grasslands) (168).

Changes in environment, ecosystems, and subsistence resources have important implications for rural communities, where indigenous people have historically led a subsistence lifestyle as hunters and gatherers (34, 122). Warming directly affects communities as a result of thinner river ice and therefore reduces safety of winter travel. Increased evapotranspiration and declining river discharge also reduce opportunities for barge delivery of fuel and increase the cost of living and therefore the dependence on subsistence harvesting (42, 67). Now that communities are permanently situated rather than semi-nomadic, increased wildfire risk constitutes the major pathway by which warming influences rural communities (42, 149) (Fig. 15). Wildfire constitutes a risk to life and property, reduces access to the land, threatens cultural resources, and reduces hunting opportunities for one to several decades (24, 43, 49, 87, 203). Sources of resilience to address these changes include traditional sharing networks that maintain community identity while sustaining food supplies to the most vulnerable households and maximizing opportunities for use of hunting equipment (122). As the abundance and distribution of subsistence resources change and access to hunting areas is modified, hunters will likely shift their hunting effort to those species that increase in availability. Development of community gardens or changes in hunting regulations to restrict competition from urban hunters could enhance resilience (122). Changes in economic conditions, such as employment in rural and urban communities, will undoubtedly interact with the effects of climate change, altering human migration patterns and the overall resilience of villages. In summary, climate warming and socioeconomic changes challenge the resilience of rural indigenous communities, but indigenous culture has proven relatively resilient to even greater threats over the past century.

Conclusions, uncertainties, and policy options

In summary, current evidence from long-term studies at the Bonanza Creek LTER indicates that unlike many other regions of the globe, ecological changes in interior Alaska are being primarily driven by climate changes, not land-use change. Research suggests: 1) Permafrost will remain relatively resilient to continued warming except in high-ice-content lowlands and in areas burned by severe wildfires. However, pervasive thickening of the active layer is likely changing the soil moisture regime of all landscapes and may contribute to shifts in ecosystem structure. 2) New successional trajectories contribute to the resilience of floodplain forests, but the long-term functional consequences (e.g., nitrogen accumulation and suitability for wildlife) are uncertain. 3) Increasingly extensive and severe wildfires and other disturbances are triggering a landscape transformation with potential expansion of deciduous forests from uplands into lowlands and north-facing slopes and perhaps the development of shrublands, grasslands, agriculture, or other novel ecosystem types in south-facing uplands and in lowlands. These transitions and associated permafrost change will likely dominate changes in regional hydrology. 4) The current mammalian fauna of interior Alaska will likely persist but reorganize into new patterns of distribution and abundance in response to both direct effects of climate and changes in habitat. Over the long term, resilience of both the animal and human communities may depend on policy decisions about the management of wildfire and human disturbances and the allocation of hunting opportunities between rural and urban hunters. Continued research by the Bonanza Creek LTER has the opportunity to inform these policy choices and therefore the regional resilience of the Alaskan boreal forest.

Section 2: Proposed Research

Introduction and Conceptual Framework

The species composition and disturbance regime of the Alaskan boreal forest have remained resilient to climate fluctuations since black spruce spread to dominate the region approximately 6,000 years ago (75, 84, 85, 130, 202). The regional landscape of interior Alaska is highly heterogeneous, dominated by a mosaic of wetlands and forests in varying stages of successional development that are adapted to and controlled by climatic extremes, cryospheric processes, and fire (36). Over the millennia, this continuously shifting landscape mosaic has been used and influenced by seasonally nomadic populations of herbivores, large carnivores and humans, entraining a trophic dynamic that in many ways remains relatively intact (36, 87, 149, 152). Despite the system's substantial resilience over long time scales, evidence is mounting that rapid climate change over the past century has altered the interrelationships among physical, biological and social drivers to influence the regional system. In this context, understanding the limits to system resilience and the consequences of exceeding resilience become crucial goals. The guiding research question of the Bonanza Creek LTER is: ***How is the boreal biome responding to climate change and what are the local, regional and global impacts of those responses?*** This question is of timely relevance for several reasons. 1) The boreal forest is experiencing among the fastest rates of warming on Earth, leading to significant climate feedbacks resulting from landform changes and associated atmospheric C, water and energy exchanges (56-58, 137, 139, 170) (Fig. 16). These feedbacks are of global significance because the boreal forest covers 12 million km^2 of the Northern Hemisphere and contains a massive pool of soil C which is vulnerable to atmospheric exchange (186). 2) Climate warming has radically changed the dynamics of and interaction among disturbance regimes, notably fire size and severity (109), surface hydrology and the rates of permafrost thaw (189), and the outbreak behavior of insects and pathogens (179, 207), resulting in apparent threshold shifts in biogeochemical cycling, successional trajectories, and ecosystem and landscape function (91, 100). 3) Subsistence hunting and gathering traditions of interior Alaskan Native communities are historically tied to interactions between the availability of subsistence resources and regional gradients in climate and disturbance regimes (87). Rural and urban human populations alike rely heavily on ecosystem services provided by the boreal forest (203). However, economic, social, and ecological changes are affecting human-ecological interactions, cultural traditions, and the provisioning and use of ecosystem services by Alaskans (24, 42, 49, 151, 203). Here we outline a program **to *understand the interactive effects of changing climate and disturbance regimes on the Alaska boreal forest, and study associated consequences for regional feedbacks to the climate system, and sustainability of subsistence Alaskan communities.*** Knowledge generated by the BNZ LTER over our previous funding cycle uniquely positions us to study the dynamics of these changes and contribute to identifying solution pathways for challenges facing boreal forest managers.

Resilience theory is increasingly recognized as a framework for studying the dynamics of social-ecological change and for adaptively managing change in ways that foster sustainability (33, 65, 215). Research across the LTER Network is demonstrating that understanding the causes of vulnerability and mechanisms for resilience are essential for interpreting change and developing strategies for managing change (26, 66, 70, 129, 161, 167). These studies emphasize that understanding the mechanisms by which legacies and feedbacks affect resilience is critical for predicting vulnerabilities to change. Further, they suggest that extreme events - surprises which are nearly impossible to predict - are likely to become more frequent as environmental change accelerates (71). The difficulty of studying extreme events necessitates large temporal- and spatial-scale studies with monitoring, experimental, and modeling programs capable of capturing these dynamics. Regime shifts, which occur when the limits of system resilience are reached, result from non-linear responses to changes in the interaction among drivers; system dynamics of new regimes are notoriously difficult to predict, and are regulated by different sets of positive (amplifying) and negative (stabilizing) feedbacks. Finally, LTER research makes it clear that ecological resilience must be studied within the broader framework of complex adaptive systems that emphasizes interdependencies of social-ecological components (29).

Recent research by the BNZ LTER has identified key feedbacks that maintain resilience within boreal forests and demonstrated how climate-driven changes in disturbance regimes are disrupting these feedbacks and resulting in regime shifts in successional pathways and landscape structure and function throughout interior Alaska (35, 91, 138). Changes in the key sources of ecological resilience are leading to threshold responses of important variables and processes and disrupting dynamics that regulate landscape structure and heterogeneity. Recent and projected trends in the interactions between changing climate and disturbance regimes are also having important consequences for ecosystem services to Alaskans. This is particularly true for rural Alaskan Native communities, which are vulnerable to the combination of climate and social-economic change given the high cost of living and reliance on the land for food (122). Within Alaska, there is a growing consensus that understanding the complex interactions among ecological, economic, political and cultural processes will be essential for developing adaptive co-management strategies in response to the extremely rapid ecological and social changes that are occurring. BNZ LTER seeks to play a major role in building and contributing to knowledge networks for the development of these strategies (42, 95, 122) (Fig. 17).

Research Design

The BNZ LTER was established to study patterns and mechanisms of boreal forest succession following fluvial and fire disturbances. For the first two decades, our monitoring program, long-term experiments and process studies focused on understanding both state factor (208) and interactive controls (39) over processes underlying vegetation change, ecosystem function, and trophic dynamics, highlighting transitions (turning points) within floodplain and upland chronosequences where successional change is most rapid. Our last proposal placed that successional research in the broader context of understanding mechanisms of resilience and the dynamics of change, and was structured around climate sensitivity, successional dynamics, thresholds and state change, and synthesis and integration. That effort expanded both our conceptual and regional scope to provide insights into how boreal ecosystems are responding, both gradually and abruptly, to climate warming, and what new landscape patterns and dynamics are emerging. Here, we build on our recent synthesis of resilience and vulnerability in Alaska's boreal forest (30), seeking to develop a more focused understanding of how key sources of ecological resilience are changing and how emerging landscape patterns are influencing climate feedbacks at local, regional and global scales. We have also substantially strengthened our studies on how climate change is affecting the ecosystem services provided to and used by subsistence-based rural villages throughout interior Alaska, and how human responses to these changes may be managed to affect social-ecological sustainability. We therefore make important changes to our research framework to study more explicitly the Alaskan boreal forest as a coupled social-ecological system.

Our proposed framework for studying social-ecological resilience and response to change is organized around four interrelated components (Fig. 18):

1. Direct effects of climate change on ecosystems and disturbance regimes. Interior Alaska is experiencing increases in mean annual temperatures and shifts in the seasonal patterns of precipitation, but also changes in modes of long-term oscillations in global atmospheric pressure and sea surface temperatures that control seasonal climate and establish modes of climate variability at decadal to multi-decadal scales (73, 77). These complex climate dynamics are having dramatic direct effects on the structure and function of the boreal landscape (14, 53, 62, 63, 189). We continue to study the direct effects of climate variability on ecosystems and disturbance regimes by 1) characterizing current and historical responses of key species and disturbances to these modes of climate variability (Table 1), 2) studying climate controls over the distribution and patterns of change in landscape functional types, and 3) experimentally manipulating climate variables in order to understand the underlying mechanisms for threshold responses of key ecosystem components and disturbance agents to change in climate drivers (Table 2). Results from these efforts will be integrated with studies on mechanisms and consequences of change in order to predict climate sensitivity of ecological communities (plant and animal species, plant functional types, community structure), ecosystem processes (NPP, C and N storage), landscape structure and heterogeneity, and the severity and distribution of disturbance regimes (fire, permafrost thaw, insect/pathogen outbreaks).

2. Climate-disturbance interactions as drivers of ecosystem and landscape change. Vegetation composition and other structural aspects of the ecosystem and landscape modulate climate sensitivity of disturbances and associated ecosystem responses to those disturbances. For example, the distribution of conifers and hardwoods on the landscape influences both fire severity and the outbreak behavior of insects and pathogens, which in turn influence the likelihood that forest communities will shift to a new stability domain. However, changing disturbance regimes also influence the climate sensitivity of species, plant communities and landscape functional types. The impacts of permafrost thaw on soil water content, for example, strongly affect vegetation responses to climate warming. Moreover, important thresholds may be manifested through interactions between changing disturbance regimes. For example, increased fire severity may increase the vulnerability of permafrost to thaw. Similarly, interactions between insect and pathogen outbreaks and fire regimes may produce novel responses by overwhelming the resilience of ecosystems to either disturbance in isolation. Understanding the underlying mechanisms for these interaction pathways is essential for predicting whether climate-driven changes will contribute to ecosystem and landscape resilience or cause abrupt shifts to a new landscape mosaic with fundamentally different dynamics.

3. Regional ecosystem dynamics and climate feedbacks. Interactions among changes in climate, ecosystem structure and function, and disturbance regimes affect exchanges of trace gases, water, and energy between the boreal forest and the atmosphere, and result in feedbacks to regional and global climate (38, 41, 56-59, 136, 139, 140, 186). Important positive feedbacks to climate warming include decreases in surface albedo due to changes in snow cover, and respiratory release of permafrost C. Negative feedbacks include increases in surface albedo due to a greater proportion of the landscape occupied by deciduous forest accompanying a shorter fire-return interval, and greater vegetation C uptake resulting from an extended growing season. Our study of the net effects of these feedbacks will use retrospective and prospective modeling to integrate field-based assessments of disturbance and climate-change effects on net ecosystem C balance with a regional assessment of the mechanisms and patterns of change in landscape structure and function.

4. Coupled social-ecological dynamics of interior Alaska. Social and climatic drivers of change are dramatically modifying the ecosystem services on which communities throughout interior Alaska depend and influencing the social-ecological interactions that link people to the land (122). For example, climate-driven changes in the physical system (77, 100, 170) and fire regimes (110) are influencing the distribution and abundances of plants and animals harvested by Native peoples of rural communities. Access to subsistence resources is increasingly limited by changes in snow cover, extent and timing of river and lake freeze-up and thaw, escalating fuel costs, and increased travel times associated with changes in landscape heterogeneity. Strong reliance and cultural ties to the harvesting and sharing of subsistence foods are fundamental to the sustainability of interior Alaskan Native communities. However, the high costs of energy, combined with limited cash employment opportunities, increasing conflicts between rural and urban subsistence hunters, and a complex governance structure for natural resource management dominated by urban interests are posing serious threats to the rural subsistence lifestyle. The BNZ LTER is partnering with Alaska Native villagers and agency resource managers to enhance resilience of rural communities through programs that facilitate adaptation and the development of fire management strategies that increase landscape diversity and ensure subsistence harvesting opportunities (42, 67, 122).

Our study design integrates these four research components across ***multiple temporal scales.*** Long-term monitoring of climate, vegetation, ecosystem function and disturbance regimes using permanent plots and satellite imagery allows us to document change at seasonal and interannual scales, while paleoecological studies of these factors provide an historical context of the past 250 years and beyond. Process studies provide insights into the importance of time lags and legacies in regulating resilience. This includes, for example, understanding how lag times in the response of plant species, traits or functional types can dampen or amplify ecosystem response to climate variability and change, or how legacies of past disturbances, such as organic matter thickness or soil N and C stocks influence ecosystem response to fire and climate warming. Finally, we use both retrospective and prospective modeling to understand the regional and global consequences of current and future vegetation and landscape change. These modeling efforts include terrestrial ecosystem models that couple biogeochemistry and soil thermal dynamics to project disturbance and climate impacts on components of terrestrial ecosystem C balance for the boreal system, and to understand water, energy and C interactions between high latitude terrestrial regions and the Earth's climate system (56-59, 136, 139, 140, 142). We also use state-and-transition succession models as a means to project regional scenarios for future fire-climate relationships in order to understand the threshold responses of these dynamics (43, 182, 203). We couple these modeling approaches to address management options of interest to policy makers working at various scales relevant to subsistence communities.

Our study design recognizes a number of key ***landscape functional types*** that differ in their interactive controls and response to climate change (Fig. 19). These are uplands, floodplains, and wetlands, which have been the focus of previous BNZ LTER research, and boreal tundra (sub-arctic tundra), which is widespread throughout the boreal region but has not been intensively studied in Alaska. Alaska contains more than half the wetlands in the U.S., and the response of permafrost to complex interactions among topography, surface and ground water, soil properties, vegetation, and precipitation is changing the distribution and functioning of boreal wetlands and tundra (100, 189). Past BNZ LTER research and long-term monitoring has been concentrated at two intensive study areas that contain representative sites for three of these landscape functional types: 1) At the Bonanza Creek Experimental Forest (BCEF), we maintain permanent plots in primary floodplain succession and secondary post-fire succession (3-5 successional stages x 3 replicate sites/stage; http://www.lter.uaf.edu/). BCEF also includes a forest-wetland gradient study where we are experimentally manipulating water-table height and summer air temperature (205). 2) At the Caribou-Poker Creeks Research Watersheds (CPCRW), we maintain four intensively-studied watersheds in upland forest, two of which are unmanipulated (low vs. high % permafrost) and two of which have burned recently (a low-severity experimental burn in 1999 (76), and a high-severity natural wildfire in 2004). During our last NSF site visit, the review team was enthusiastic about our new focus on the mechanisms and feedbacks controlling boreal forest resilience, but also recognized that our long-established monitoring program within the BCEF provided limited support for studying threshold responses of boreal landscapes to changing climate and disturbance regimes. Following their recommendation and informed by recent analyses of our long-term data sets (80, 141, 232), we are scaling back monitoring programs within the BCEF without compromise to the long-term record of vegetation change and NPP. This is allowing us to expand regional monitoring of landscape change across a network of black spruce sites that have been studied by BNZ researchers (72, 82, 93, 131, 159, 189), but have not previously been incorporated into our long-term monitoring program.

The BNZ LTER **research strategy** has been to assemble a team of highly motivated boreal scientists who collaborate effectively, to provide them with a research infrastructure consisting of long-term measurements on permanent plots and experiments and data management services, to provide enough funding for each investigator to study the long-term ecological dynamics of their focal interest, and to encourage them to seek external funding for process studies that explore the underlying mechanisms. The research described here is the long-term LTER research funded by the NSF and USDA Forest Service. We mention (but do not describe) the mechanistic research that is funded elsewhere (see Table 8 in Budget Justification). Detailed methods for tasks described below are presented at http://www.lter.uaf.edu/proposal2010/bnz_2010methods_outline.cfm.

I. Direct effects of climate change on ecosystems and disturbance regimes

Hypothesis 1: Changes in temperature and precipitation are influencing ecosystem structure and function at multiple temporal scales through effects on key species, functional types and disturbance regimes, resulting in modifications to landscape structure and heterogeneity.

Question 1. What are the direct and indirect effects of climate change on key species and functional groups?

The boreal forest, located in the very cold, continental climate of interior Alaska, might be expected to be highly sensitive to the direct effects of climate warming. In our prior research, however, we have shown that indirect effects of warming predominate. There is increasing evidence, for example, that responses to warming are increasingly constrained by moisture availability, which has declined as precipitation has failed to increase as rapidly as temperature (77). Both satellite NDVI data and tree-ring analyses suggest that tree growth and forest productivity have declined in recent years, most likely as a result of drought stress (20, 48, 69, 127). Our research on climate sensitivity in the next phase of the BNZ LTER will thus emphasize the interactive effects of temperature and precipitation on key species and functional groups. We are expanding beyond past research by establishing a new set of sites that will provide a regional-scale perspective on ecosystem response to climate change, and by broadening the study to include an analysis of climatic controls over growth and success of dominant tree species (aspen, birch, black spruce) about which less is known. In the eastern boreal forest, these species differ significantly in their response to temperature and moisture and in their overall sensitivity to climate (86); understanding interspecific differences in response to climate variation in the more moisture-limited boreal forests of Alaska is an important research goal.

Task C1 (i.e., task 1 of the direct climate effects section): Quantify the influence of site drainage and stand age on the climate sensitivity of vegetation communities and ecosystem function within black spruce forests at the regional scale. The BNZ LTER will establish a new regional network of research sites to regionalize our understanding of resilience and mechanisms of ecosystem responses to climate change in black spruce forests. The design of this new network is informed by recent studies of how parent material, topography, permafrost status (collectively associated with site drainage) and fire severity affect successional trajectories and ecosystem processes of black spruce forests at the regional scale (79, 83, 95, 131). Sites will be situated within the 3 ecoregions of interior Alaska (Fig. 20). Within each ecoregion, 4 stand-age classes of three different site drainages will be established (n=36) in which we will monitor climate variables, overstory and understory vegetation composition, and productivity of dominant tree species. Study sites have already been established in several mature black spruce stands within the BNZ-LTER framework of floodplain and upland “turning points” of succession. These sites have been monitored for the past several decades and will be incorporated within the proposed new network of sites. This expanded network of long-term research sites will dramatically extend our regional scope and become the focus of the BNZ LTER for the next several decades. We detail information concerning the climate, geomorphology and vegetation of these regions, methods for site selection and implementation of the proposed monitoring program within the site management network in the online methods section for this task. In addition, we describe our methods for scaling back measurements associated with the turning points conceptual framework without compromising valuable long-term data sets.

Task C2: Based on tree-ring measurements and historic satellite data, determine trends in productivity from a longer temporal and larger spatial perspective. We propose to continue dendrochronological and remote sensing investigations of within- and among-species patterns of variation in climate response and sensitivity by focusing on two research gaps related to our understanding of heterogeneity in climate response. First, although climate sensitivity has been well-characterized for white spruce, little is known about other boreal tree taxa (e.g., aspen, birch, balsam poplar, black spruce). Second, from a remote sensing perspective, little is known about patch-scale variation in contribution to the regional trend in declining NDVI (210). We will focus our investigations within the landscapes of the BNZ and CPCRW sites. The BNZ area will be sampled along a ridgeline where stands of south-facing white spruce and aspen/birch occur within a few hundred meters of stands of north-facing black spruce and birch. This area thus encompasses different thermal and radiative microclimates within a similar precipitation regime. The CPCRW area includes an elevational gradient ranging up to tree line and thus encompasses variation in both temperature and precipitation. Within each of these areas, historic Landsat sensor data will be used from the mid-1980s to present to determine the NDVI trend within landscape types (floodplain, south-facing upland, north-facing upland) and within functional vegetation patches (for example, upland white spruce, upland black spruce) to determine negative and positive responders from a patch perspective. Landsat scenes from mid-June to mid-August, the time period in which NDVI typically peaks, will be used to compute NDVI at the patch scale from the mid-1980s to present.

Dendrochronology will compliment the remote sensing by improving the temporal depth. Tree-ring data will also serve as a source of validation of the short-term (1980s-present) remotely sensed NDVI trends, and provide information on the degree to which the NDVI data are reflecting changes in the productivity of trees (as compared to other functional types). Our tree-ring analyses will make use of existing unpublished tree-ring data from CPCRW and BNZ, with some collection of new data targeting sites with satellite coverage but lacking tree-ring data. Details on new and existing tree-ring collections are provided in the online methods.

Task C3: Manipulate the amount and seasonal timing of soil moisture availability to assess influences on productivity of dominant coniferous species. Results from our 10-year summer rainfall exclusion experiment in mid-successional upland and floodplain mixed hardwood-white spruce forests suggested that early growing season soil moisture dynamics are tied to the soil moisture recharge from melting snow pack, and subsequently influence soil C and N mineralization and primary productivity during the growing season (232). To test this hypothesis, we recently implemented a long-term experiment that directly limits soil water recharge by removing snow in the spring from plots within floodplain balsam poplar/white spruce and upland birch/aspen/white spruce stands. Because snow is removed from covers placed on the forest floor installed immediately before snowfall, the forest floor is snow-covered during winter, and thus, wintertime soil temperatures are unaffected. Aboveground production, total belowground C flux, and N-cycling parameters are being measured annually. In addition tree sap, rainfall, throughfall, soil moisture and river water samples are being analyzed for hydrogen and oxygen isotope quantities to allow us to trace the source of water for tree growth. The BNZ LTER is seeking outside funding to implement a rainfall (frequency and intensity) manipulation experiment examining GPP partitioning in black spruce forests.

Task C4: Document the effects of climate variability, vegetation type, and predation on vertebrate herbivore abundance along a latitudinal boreal transect. Our research focuses on two important herbivores (moose and snowshoe hares) known to be sensitive to interannual climate variability, particularly snow depth (Fig. 14). We continue to estimate snowshoe hare population parameters throughout the year within the BCEF using mark-recapture methods, and have recently established two additional trapping grids in the Brooks Range approximately 400 km north of Fairbanks near the distributional limit of snowshoe hares. In addition to basic demographic data pertaining to population growth rates, population densities, body condition and recruitment, we use radio telemetry to study seasonal variation in survival to gain a better understanding of the relative importance of climate, forage availability and predation in controlling snowshoe hare populations. Data on moose demography (population densities, annual population growth rates, recruitment and survival) from the AK Dept of Fish & Game contribute to our ongoing modeling of the interactions between moose browsing, winter severity and fire, and population data for both species are closely tied to our vegetation monitoring program.

Question 2: What are the direct effects of climate on disturbance regimes?

Climatic effects on disturbance regimes are a key avenue by which climate changes are likely to affect the structure, function, distribution, and resilience of boreal ecosystems. Indeed, there is mounting evidence that warming in recent decades has already led to changes in boreal forest disturbance regimes (10, 100, 111, 165). We address three key disturbance agents in the interior boreal forests: fire, permafrost (which acts as a disturbance agent as it warms and eventually thaws), and outbreaks of insects and pathogens. All three are expected to be vulnerable to climate warming. In the case of fire and insects, however, the relative importance of weather, site conditions, and landscape heterogeneity as controls over disturbance regimes remains uncertain. In this section, we consider the direct effects of climate on each disturbance agent; in subsequent sections of the proposal we address the interactions among climate, disturbance, and ecosystem function.

Task C5: Determine whether key aspects of the fire regime covary in space and time, and if the sensitivity of fire regime to climate is consistent across different ecosystems and landscapes. BNZ LTER researchers are collaborating with fire ecologists from universities and state and federal agencies through a number of funded research projects (NASA, USGS, NSF, JFSP and USFS) to understand controls over boreal fire regimes. Much of this goal is thus met by externally funded research. We propose, therefore, that the BNZ LTER serve a coordinating function among these various projects, promoting synthesis and collaboration to address this broader question about the climate sensitivity of boreal fire regimes. We propose to develop a series of annual workshops bringing the scientific community together to facilitate collaborations among those projects by a) compiling geospatial data sets necessary for examining spatial/temporal characteristics of Alaska's fire regime, b) identifying critical gaps in our understanding of boreal forest fire behavior, and c) fostering network activities among these research groups. In addition, these workshops would provide the means for graduate students and post-docs who are working on LTER-related activities but are not from UAF to have more meaningful interactions with other LTER scientists. A proposed schedule and anticipated products resulting from these workshops are available in the on-line methods section of this proposal.

Task C6: Examine the relationship between seasonal and interannual variability in climate and permafrost temperature across a range of ecosystems, and couple these observations to model projections using future climate scenarios. To analyze the dependence of the present thermal state of permafrost (temperature and active layer depth) on climate variability and ecosystem structure, we will continue monitoring seasonal and interannual variation in permafrost and ground temperature profiles at core BNZ permafrost monitoring sites which cross several geomorphologic features with varying soils and vegetation. To model the effects of changes in climate (temperature and precipitation) and variation in ecosystem structure at multiple time scales (decades to millennia), we will use GIPL (http://www.gi.alaska.edu/snowice/Permafrost-lab/methods/modelling.html), which simulates soil temperature dynamics, depth of seasonal freezing and thawing, and liquid water content fields for the complete profile, with varying organic matter thickness representing different ecosystem types (Fig. 21). Model output can be validated with data from the core permafrost monitoring sites, and from other BNZ LTER sites where soil temperature and moisture are measured and/or manipulated experimentally. Manipulation experiments are described more fully in *Section 2b*, and will provide datasets for a variety of climate treatments including summer warming and winter warming alone and in combination. The understanding gained from analyses involving GIPL, which models permafrost thermal dynamics at very fine temporal resolution, will inform the development of DOS-DVM-TEM, which is being used in the modeling research proposed in *Section III* to dynamically couple thermal, hydrological, and ecosystem processes during succession.

Task C7: Assess historical patterns of insect and pathogen outbreaks, and determine how recent summer warming and associated plant drought stress are affecting insect herbivore populations and outbreaks of key plant pathogens. We will continue monitoring key phytophagous insects (102, 213) and alder stem canker (179) to build the long-term data sets necessary to understand the role of climate in triggering outbreaks. Coordinated BNZ LTER tree growth measurements and insect/pathogen monitoring have revealed temperature thresholds for spruce budworm (SBW) (Fig. 22), but we are just beginning to understand climatic influences on, and plant physiological responses to, outbreaks of aspen leaf miners (ALM) (213) and alder stem canker (ASC) (174, 179). We will also initiate new dendrochronological studies to further describe how insect outbreaks are affecting forest productivity, using tree ring width as an index of the magnitude and duration of effects on productivity. We will also attempt to reconstruct past outbreak periods for spruce budworm and aspen leaf miner from tree-ring analyses of host species. We will identify past outbreaks by calibrating ring-width responses to known historical outbreaks, and by comparison of ring-width patterns of host species to those of co-occurring non-host species (198). Suitable non-host species will be identified based on the known feeding preferences of phytophagous insects combined with productivity data from mixed-species stands during recent outbreaks.

II. Climate-disturbance interactions as drivers of ecosystem and landscape change

Hypothesis 2a: Climate-driven changes in fire regime interact with environmental conditions and vegetation structure to alter ecosystem function and structure, and successional pathways (Fig. 23).

Question 1. How does vegetation composition and ecosystem structure affect the climate sensitivity of the fire regime?

Ecosystem flammability can amplify or override the direct influences of climate change on the fire regime (75). Flammability is related to species composition, stand age, and environmental characteristics such as aspect and drainage. Hardwood tree species, for example, have historically acted as a negative feedback to fire severity because of high leaf water content and low flammability of litter (40, 74). If increasing fire severity drives an expansion of hardwood or mixed spruce-hardwood stands across the landscape, then landscape flammability may decrease, reducing fire severity, increasing fire return time, and promoting landscape resilience (91). As climate warms, however, vegetation effects on flammability may decline, potentially weakening this negative feedback (110). Understanding the interactions between climate and vegetation flammability is crucial for predicting the future AK fire regime.

Task D1 (i.e., task 1 of the disturbance-climate interactions section): Determine the historic fire return interval for key vegetation types, stand ages, and landscape positions, and examine the potential for positive and negative feedbacks between changing vegetation composition and fire frequency. We will assess historic fire return intervals using expert opinion and a synthesis of available data on stand age distributions as part of our fire regime synthesis workshops described in *Task C5*. We also will use modeling simulations in a landscape fire and vegetation model (ALFRESCO, see *Section III*) to examine how changes in forest successional trajectories and landscape cover caused by changes in the fire regime may feedback to influence future fire behavior under different scenarios of climate change.

Question 2: What are the consequences of a changing fire regime for plant communities, ecosystems and landscapes?

Plant-soil-microbial (PSM) feedbacks among black spruce, mosses, and microbial decomposition maintain deep organic soils in forests of interior Alaska (Fig. 24). This internal feedback has been a key source of ecosystem resilience under the historical fire regime; moist, cold soils, poorly drained due to permafrost, burn at low severity and create a seedbed that favors the re-establishment of black spruce (91). In extreme fires, however, these soils can burn deeply (15) and when less than 3-8 cm of organic soil remains after fire, hardwood tree species such as aspen and birch establish at high densities (91, 93, 94) and catalyze a switch to an alternate successional trajectory, where spruce and hardwoods are co-dominant. Here, a new PSM feedback domain emerges, where warmer shallow organic soils are maintained by rapidly decomposing litter from highly productive hardwood species. Loss of permafrost is likely once this threshold is reached (236), further amplifying high rates of decomposition and decreasing accumulation of soil organic C.

Species are likely to respond individualistically to both the direct effects of disturbance, and to altered internal feedbacks. These responses could have important impacts on biological diversity, species interactions such as those between plants and microbes or plants and herbivores, and the abundance of keystone plant species that exert strong influences on ecosystem processes such as biological nitrogen fixation. Furthermore, shifts between spruce and spruce-hardwood mix feedback domains have large implications for ecosystem productivity and C storage (69, 131), C and energy feedbacks to regional climate (166), and the goods and services that boreal ecosystems provide to humans. The goal of our proposed research in this section is to develop a mechanistic understanding of how an altered fire regime will affect the establishment of 1) key plant species and 2) successional trajectories, and 3) to identify the consequences of alternate successional trajectories for ecosystem and landscape processes.

Task D2: Determine how the establishment and persistence of key plant species post-fire are regulated by microbial communities, plant interactions, and herbivores. We will study the influence of fire on mycorrhizal-seedling associations, plant competition and facilitation, and herbivore dynamics across a network of post-fire sites of various time-since-fire, fire severity, and fire size. We already know that fungal diversity varies among sites with different understory communities (Fig. 25). To determine if there is fungal limitation to tree seedling establishment and post-fire community composition, we will fingerprint post-fire fungal communities and sequence key mycorrhizal taxa that may be critical to seedling establishment. We will outplant seedlings in recently burned sites that are inoculated with various fungal communities and monitor growth, vigor, and survivorship. We will determine if post-fire regenerating willow and birch species act as “nurse plants” for fungal communities that are critical for tree seedling growth. The presence and abundance of colonizing native and non-native N-fixing plants could also shift post-successional trajectories dramatically. To test invasibility of recently-burned sites, we will grow N fixers in a variety of burn substrates, monitor growth, vigor, and survivorship and assess nodulation rates. We will assess the importance of post-fire bryophytes to the establishment potential of key early colonizers by out-planting native N fixers on different bryophyte and mineral substrates in recent burns. Forage availability and the potential effects of browsing pressure on post-fire vegetation succession will be evaluated by surveying sites with various abundances of willows, the primary browse genus for moose, for differential browsing intensities.

Task D3: Determine the effects of an altered fire regime on successional trajectory. We will test the general hypothesis that increasing fire severity catalyzes a switch to alternate successional trajectories in boreal black spruce forests (Fig. 26) by following tree establishment and community composition in 90 permanent study sites that burned in 2004. These sites extend throughout interior Alaska and span a broad range of soil moisture and burn severity. Through repeated surveys of seedling recruitment, we will determine the frequency and conditions under which the new successional trajectory will differ from that of the pre-fire vegetation. We will use these data to test, within a landscape context, simple hypothesized rules to predict successional trajectory based on fire severity, pre-fire vegetation, and nearby seed sources (95). We will also experimentally test the demographic mechanisms driving these switches. We have sown seeds and planted seedlings of the major boreal tree species (including lodgepole pine, which is migrating westward in the Yukon (92)) in 38 sites that burned in 2004 and exhibit a range of soil moisture and fire severity. In 2012, we will resurvey seedling survivorship, growth, and nutrition to determine the circumstances under which each species might establish and become competitively dominant.

Task D4: Determine the ecosystem and landscape consequences of an altered fire regime. We will continue our work characterizing plant and soil C and N pools, plant productivity, and soil N dynamics in sites that vary in fire severity across three age groups of sites (Fig. 27): 1) the 90 permanent study plots that burned in 2004 (see above), 2) 45 intermediate-aged stands (20-60 years after fire) nested within 15 fires that vary in hardwood:spruce ratios, and 3) 35 mature stands (>70 years after fire (81)). From this suite of sites, we will construct empirical models of the relationship between time after fire and C and N accumulation, plant productivity, or soil N dynamics for both spruce and spruce-hardwood mixed trajectories. These models will be used to predict the consequences of a changing fire regime for landscape-scale C cycling and energy fluxes, and will provide information for parameterizing and testing the C dynamics of DOS-DVM-TEM (see Section III). In a subset of these sites, specifically those incorporated into the new LTER core monitoring sites (*Task C1*), we will use experimentation to better understand controls over PSM feedbacks. We hypothesize that productivity will be highest in the mixed spruce-hardwood trajectory, peaking in intermediate-aged stands because of high rates of N supply maintained by rapidly decomposing hardwood litter. Soil organic C accumulation, by contrast, will be highest in the spruce trajectories throughout succession because of high rates of moss productivity and slow rates of moss and spruce litter decomposition. We will test these hypotheses by reciprocally transplanting mosses, plant litter, and intact soil cores among sites that vary in stand composition within each of the three age classes. By comparing the relative influence of site of origin and site of incubation, we will determine the importance of stand environment versus plant litter quality for maintaining key processes in the PSM feedbacks, including moss growth, litter decomposition, and soil N dynamics (Fig. 24). Further exploration of stand microclimate, including permafrost dynamics, microbial community composition, herbivory and disease, and inherent growth potential of tree species will help us refine our understanding of biotic and abiotic contributions to these feedback cycles.

Hypothesis 2b: Ecosystem structure and soil drainage characteristics modulate both climate change disturbances *to* permafrost, and the ecological and hydrological *outcomes* of changing permafrost (Fig. 28).

Question 1: How does variation in the amount of remaining organic matter following fire affect permafrost temperature?

Permafrost thaw is expected as a result of warming temperatures and increased precipitation (*Task C6*). The influence of air temperature on permafrost is modulated by the amount of surface insulation in the form of snow and organic soil layers, but in different ways. Deeper snow slows winter heat loss from soils and can warm permafrost temperature, whereas thicker organic soil layers attenuate the influence of summer air temperature and can keep permafrost temperature cool. Vegetation structure and surface moisture tend to covary with organic soil layer thickness in the boreal forest, with wetter sites promoting thick organic soil layers; yet such wet sites also have open canopies promoting deep snow cover. Thus, the seasonal distribution of precipitation over the course of a warming climate is complex. Widespread decreases in soil organic layer thickness via combustion are a feature of boreal fires as are increases in thickness of snow cover, thus disturbance by fire and permafrost thaw interact but are not easily modeled or predicted. These ecosystem controls over permafrost degradation are the subject of the first set of tasks below.

Task D5: Examine the relationship between organic soil layer remaining following fire and permafrost temperature across a range of ecosystems, and couple these observations to model projections using future fire and climate scenarios. We will use the GIPL permafrost model to assess the effects on ground temperature of changes in surface organic layer properties caused by fire (*Task C6*). The model will be parameterized with site temperature data from a range of black spruce forest stands (*Task D3*) that vary in original (pre-fire) soil organic layer thickness and in the proportional consumption of this layer by fire. This framework will allow us to distinguish the effects of fire on permafrost temperature across a range of ecosystems that differ in structure. The methodology for this task is directly related to *Task C6*, but is also included here because we are describing interactions between disturbance types (fire and permafrost degradation). The research with GIPL in this task will inform the development of DOS-DVM-TEM in *Section III*.

Question 2: How do the effects of permafrost thaw on surface hydrology differ between better-drained vs. poorly-drained ecosystems, and what are the consequences for ecosystem structure and function?

Permafrost thaw alters ecosystem structure and function, with disturbance severity and soil drainage characteristics as primary controlling factors of successional trajectory. Once permafrost degradation is initiated, the consequence for ecosystems and their future successional trajectory depends on ecological and hydrological processes that can vary across the landscape depending on site attributes. Disturbance to permafrost structure and distribution can occur as a gradual change, such as a thickening of the seasonally thawed *active layer* that can eventually lead to development of a *talik*, the bottom of the deepened active layer that does not refreeze during winter. It also occurs abruptly in the form of catastrophic ground subsidence (*thermokarst*), sometimes coupled with erosion, as ice melts from within the soil profile and water drains away. These modes of permafrost disturbance are linked to ecosystem attributes such as topography (slope), ground ice content including the presence of massive ice wedges and thick ice lenses, permafrost temperature, and properties of the soil and underlying geology that affect drainage. In turn, these modes determine whether disturbance by permafrost thaw leads to near-primary succession at one end of the spectrum, to secondary succession, or even, at the other end of the spectrum, to just a shift in the competitive balance among extant species as a result of shifting resource availability. Aside from disturbance intensity, one of the other primary factors controlling ecosystem response and future successional trajectory is the hydrologic regime following permafrost thaw, in particular because permafrost restricts drainage and can control surface hydrology. Permafrost degradation can change surface hydrology substantially, resulting locally in poorly-drained wetlands and/or thaw lakes, especially in areas where drainage is restricted by underlying soil, geological substrates, or impermeable deep ground ice, or in low-slope areas. Alternately, permafrost thaw can result in well-drained ecosystems where higher slopes or more permeable soils or geological substrates allow for deeper flowpaths and better surface drainage. These represent endpoints of a moisture continuum that are the subject of the second set of tasks designed to capture the overall landscape-level consequences of permafrost thaw in the boreal region (Fig. 29).

Task D6: Examine the coupling among permafrost distribution and thaw, and soil and vegetation structure on watershed hydrology and stream export of C and N in upland boreal forest catchments. BNZ LTER research examining the coupling among climate, permafrost, soils and vegetation with watershed hydrology and stream solute exports has been focused in CPCRW and builds on approximately 30+ years of stream flow and climate measurements. Ongoing studies focus on characterizing the consequences of variation in permafrost distribution and thaw, and changes in temperature and precipitation on C and N fluxes through catchments that differ in the extent of area underlain by permafrost. We will continue to measure stream discharge and solutes in our study streams and couple an end-member mixing analysis and flowpath modeling (45) with stream C and N fluxes to determine how pathways of element loss differ in watersheds with varying amounts of permafrost (12, 23). In addition we have been monitoring a sub-catchment of the CPCRW that burned extensively in 2004. We have several years of pre-fire stream discharge and chemistry data providing rare background information to study fire disturbance effects on permafrost thaw, stream hydrology, and nutrient fluxes (13) (Fig. 13). We have started monitoring several new streams that formed as a result of localized thermokarst coupled with erosion that occurred in an unburned catchment within CPCRW, potentially enabling us to identify thermokarst influence on stream C and nutrient exports. In addition to our stream measurements, we will focus on four variables that are key to developing an integrated landscape perspective of the effect of permafrost thaw on ecosystem structure and function. The following variables will be measured at CPCRW and in contrasting sites affected by different modes of permafrost thaw (including *Tasks CF2* and *CF3* below): 1) soil environment (temperature, moisture, water table, and active layer depth), 2) radiocarbon age of DOC, 3) exchange of CO_2 and CH_4, and 4) species composition and productivity.

Task D7: Examine the effect of natural and manipulated permafrost thaw on vegetation structure, and ecosystem C and N cycling in upland boreal tundra landscapes. Expanding on the experimental design at CPCRW that relied on differences in the extent of underlying permafrost among different catchments, we initiated work at Eight Mile Lake (EML) watershed in order to more accurately capture the disturbance effect of widespread permafrost thaw and thermokarst at the watershed scale. This watershed has been undergoing permafrost thaw and ground subsidence on a landscape scale much larger than represented at CPCRW, and over longer decadal time periods. Our research along a natural experimental gradient of permafrost thaw has shown that where permafrost thaw has caused more extensive ground subsidence, the plant community composition has shifted from graminoid to shrub dominance (187, 189). We have documented significant losses of soil C with permafrost thaw that, over decadal time scales, overwhelm increased plant C uptake at rates that could make permafrost a large biospheric C source (Fig. 30). To expand this plot scale work on the permafrost thaw gradient to the landscape scale we have installed an eddy covariance system to explore seasonal and interannual C exchange, and to increase the frequency of wintertime measurements, providing essential information on the C cycle during this important season. This allows us to extend C balance measurements beyond our previous 5-year dataset based on autochamber measurements, and to couple with future C balance measurements at the relocatable NEON site located adjacent to the EML watershed. Additionally, we have been monitoring C loss in streams to understand the impact of lateral C exports on ecosystem C balance at the scale of the entire EML watershed (192, 193). In 2008, we initiated a new deep-soil warming experiment that couples winter snow pack manipulation with open top chambers to impose both summer and winter warming alone and in combination in order to quantify the effect of warming on vegetation biomass and NPP, permafrost degradation, ecosystem C fluxes and balance, and old C loss (Fig. 31). Together the natural thaw gradient and the warming manipulation provide complementary insight into the effect of permafrost thaw on ecosystem structure and function at short and long timescales. We will use this group of study plots and the integrated variables (soil environment, dissolved C and nutrient losses, CO_2 exchange, and plant species composition and productivity) described in *Task CF1* above to extend our conceptual and quantitative understanding to areas where abrupt thaw and thermokarst is the major mode of disturbance to permafrost.

Task D8: Examine the effects of natural and manipulated permafrost thaw on vegetation structure and ecosystem C and nitrogen cycling in boreal wetland landscapes. Poorly-drained boreal ecosystems represent the other end of the continuum of soil drainage that has a major influence on the response of ecosystems to permafrost thaw (Fig. 5). These systems are an important component of the boreal region, but are not represented by our relatively well-drained sites at CPCRW and the EML watershed. (Poorly-drained black spruce sites will be included within the new extensive site network. *See Task C1*). We initiated studies of vegetation structure and C cycling in fens and bogs at BCEF to understand how permafrost thaw affects the trajectory of ecosystem succession in poorly drained ecosystems. In this area, the Alaska Peatland Experiment (APEX) was established to manipulate winter and summer soil temperatures by changing snow depth and using open top chambers, respectively. In addition, water table is being manipulated in sites varying in permafrost regime (205). We will use this group of study plots and the integrated variables (soil environment, dissolved C and nutrient losses, CO_2 and CH_4 exchange, and plant species composition and productivity) to extend our conceptual and quantitative understanding of permafrost thaw in poorly-drained areas where water logging is a major control over ecosystem structure, function and successional trajectory.

Hypothesis 2c: Climate-driven changes in outbreaks of defoliating insects and plant pathogens affect successional pathways and ecosystem function by altering the abundance of key plant species (Fig. 32).

Question 1: How do stand structure (age and density) and plant stress (drought, and other pest agents) interact to influence pathogen and herbivorous insect outbreaks?

The recent outbreak of aspen leaf miners (*Phyllocnistis populiella*) in interior Alaska has provided an opportunity to study the physiological mechanisms responsible for reductions in aspen growth and leaf longevity (213). We have shown that both phenolic glycosides and extrafloral nectaries in aspen deter leaf miner herbivory (145, 237, 238), but expression of both declines as plants grow larger (50, 51, 238), suggesting that stand age (i.e., time since fire) may be an important driver of aspen leaf miner outbreaks at the regional scale. Similar stand-level control over pathogen outbreaks appears likely for the recent outbreak of alder stem canker (*Valsa melanodiscus)*, where incidence of disease and related mortality are inversely correlated with alder density (154, 179) (Fig. 33). In south-central AK, canker-induced declines in alder nodule biomass increased with degree of defoliation by the invasive alder sawfly (*Monsoma pulveratum*) (179), suggesting that if and when this sawfly invades interior Alaska, it may exacerbate and/or prolong the current alder canker epidemic. We have also characterized how growing-degree thresholds affect developmental rates, over-winter survival, and thus the outbreak behavior of spruce bud worm (*Choristoneura fumiferana*) in interior Alaska (102), but know little about how stand density or age structure of white spruce influences landscape patterns of attack.

Task D9: Coordinate monitoring of the abundances of native and invasive insects and pathogens with measurements of plant growth, community composition and stand structure. In order to better understand the impact of changes in herbivorous insect populations on ecosystem variables, we will more closely integrate our annual surveys of forest insect abundance (*Task C7*) with ongoing measurements of forest production and species composition. In 2011, insect abundance surveys will be assumed by the US Forest Service's Forest Protection Fairbanks Unit. We are currently discussing ways to modify data collection at that time, to better link the insect surveys with LTER ecosystem measurements while preserving the integrity of the long-term data set. This may involve relocating insect survey sites to areas in which LTER monitors plant and ecosystem variables.

Question 2: How are changes in the abundances of herbivorous insects and plant pathogens influencing plant growth, biogeochemical cycling, and browsing by large mammals?

Vertebrate herbivores (moose and snowshoe hares) play a prominent role in successional processes and ecosystem dynamics by modifying the competitive balance among plant species (18, 19, 114) and altering the pathways and rates of C and nutrient cycling (21, 22, 114, 115, 117, 176). Because N-fixing alders are heavily-defended chemically and avoided by browsers, spatial and temporal variations in vertebrate trophic cascades have long-term consequences for N cycling (21, 22, 154). Herbivorous insects and plant pathogens interact with climate variability and change to influence plant growth, vegetation community composition and ecosystem structure and function (2, 179, 213). And although it is likely that pest and pathogen outbreaks are both influencing and being influenced by mammalian herbivores, interactions between vertebrate and invertebrate herbivores are poorly studied in interior Alaska (153, 173, 197). Recent outbreaks of alder canker and willow leaf-blotch miners (WLBM, *Micrurapteryx salicifoliella*), in combination with pronounced regional variation in the abundance of moose (21, 22) offer a unique opportunity to begin to study these interactions. The BNZ LTER will initiate two new long-term experiments to begin studying interactions between vertebrate herbivore browsing preferences, pathogen and pest outbreaks, successional trajectories and biogeochemical cycling.

Task D10: Quantify the effects of alder canker on N-fixation inputs and associated rates of plant growth and successional patterns of C and N storage. The outbreak and spread of the alder stem canker, and associated impacts on N-fixation inputs, successional processes, and ecosystem function are controlled by a complex interaction among climate warming, disease epidemiology, and alder population dynamics (155, 179). Because vertebrate herbivory on willows favors alder growth and the incidence of canker increases with alder density, temporal and regional variation in browser abundance appear to indirectly influence disease-related declines in N fixation inputs. We continue our long-term canker monitoring plots (*Task C7*) to document disease effects on alder growth and mortality, N fixation rates, nodule biomass and N-fixation inputs (179). In 2009 we initiated a willow-removal experiment to test its effects on alder recruitment along the Yukon River, where heavy predation by wolves and bears maintains low moose numbers and high willow densities that prevent alder stand development. Stem canker is nearly absent from alders growing along the Yukon River, but this may change if increased willow browsing permits dense alder stands to establish. In addition to characterizing N cycling processes across this network of natural and manipulated alder densities, we will regionally expand our Tanana River study of alder-effects on mycorrhizal communities, P cycling, and rates of C storage.

Task D11: Manipulate the abundance of insect and vertebrate herbivores in early successional stands and assess consequences for plant growth, biogeochemical cycling, and vegetation development. Building on the long-term BNZ LTER vertebrate herbivore exclusion experiments, we will initiate a new study of the ecosystem and plant community responses to the willow leaf blotch miner, one of the insect species to irrupt recently at large spatial scales in Alaska (207). This new long-term experiment will test the direct and interactive effects of invertebrate and vertebrate herbivores on early-successional communities using a 2-way, split plot factorial design, with vertebrate exclusion as the whole plot factor and invertebrate exclusion as the sub-plot factor. Invertebrates (in particular the WLBM) will be excluded using insecticide in early June, when vulnerable eggs and small larvae are present. Our intent is to test the effects of irruptive densities of the WLBM in a targeted manner, as we have done successfully for the con-familial aspen leaf miner (213). Because not every year will be an irruptive year for the moth population, this experiment will require at least a 10 year commitment. In addition to our annual measurements of a suite of plant growth, community composition, and nutrient cycling parameters (see Methods), the experiment will provide infrastructure for researchers to explore additional response variables, such as mycorrhizal associations, soil microbial diversity and function, plant defensive chemistry, and invasibility of the plant community. The experiments and observations in *Tasks D10-11* provide information to validate models of herbivore effects on willow-alder competition (64).

III. Regional Ecosystem Dynamics and Climate Feedbacks

Hypothesis 3a: Responses of boreal ecosystems in interior Alaska to projected changes in climate and disturbance regimes will directionally shift vegetation distribution towards more deciduous forest cover primarily through increased disturbance frequency and severity, leading to successional pathways that allow regeneration by deciduous tree species at the expense of conifer tree species.

Question 1: How will interactive responses of disturbance regimes, ecosystem structure/function, and successional pathways to future climate variability and change influence regional ecosystem dynamics?

Our proposed research primarily focuses on interactive responses of fire, ecosystem/structure, and successional pathways to future climate variability and change. We have previously made progress on considering the effects of herbivory with one of our modeling tools (ALFRESCO, 14) and we have ongoing research projects that are making progress on considering the effects of herbivory and insect disturbance with TEM (see McGuire C&P). As our research program evolves we will consider herbivory and insect disturbance in addition to fire based on the research proposed in *Section 2c*, but our first efforts will focus on fire disturbance as we are well poised to comprehensively evaluate these responses. Incorporating a full suite of disturbances (herbivory, fire, and insects) in the modeling tools developed in this section is important to support the ecosystem services research proposed in *Section IV*. In this study we will use two models that have focused on describing various aspects of linkages among climate, fire, and ecosystem structure and function. 1) The Alaska Frame Based Ecosystem Code (ALFRESCO) was originally developed to simulate the response of sub-arctic vegetation to a changing climate and disturbance regime (181, 184). 2) The dynamic organic soil – dynamic vegetation model version of the Terrestrial Ecosystem Model (DOS-DVM-TEM), which simulates the major dynamics of C and N fluxes and pools in boreal forest ecosystems, explicitly models how fire disturbance and post-fire vegetation recovery affect the structure of the soil, and how different plant functional types compete for light, water, and N. The dynamic organic soil component (233-235) and vegetation component (58) of DOS-DVM-TEM have been described.

ALFRESCO models the relationship between monthly climate variables and flammability of a given grid cell. Fires are stochastically ignited and then burned recursively. The fire routine in ALFRESCO generates patterns of burning on the landscape that are consistent with the frequency, size distribution, and area burned observed in the historical record since 1950 (182) (Fig. 34). ALFRESCO also models the changes in vegetation flammability that occur during succession through a flammability coefficient that varies with vegetation type and stand age (37).

TEM has been used to estimate fire emissions and the C dynamics of northern high latitude ecosystems across the pan-boreal region (8) and the North American Boreal Region (7). Fire disturbance implemented in these model versions reduced the amount of soil C without affecting organic soil thickness and associated changes in the thermal and hydrological properties of soil (6, 8). To help overcome this shortcoming, Yi et al. (234) explicitly coupled soil thermal and hydrological processes of TEM so that the model was capable of simulating soil environmental changes in the context of changing soil organic thickness (Fig. 35). There are 4 components in dynamic organic soil version TEM: 1) the environmental module (EM; (233)), 2) the ecological module (EcoM; (235)), 3) the fire disturbance module (FDM; (235)), and 4) the dynamic organic soil module (DOSM; (233-235). The ability of the EM to simulate the dynamics of the soil environment will be further evaluated across a broad range of boreal ecosystems based on information from *Task C1, C6* and *D6*. The abilities of the FDM to simulate the loss of soil organic thickness in fire and the DOSM to simulate the growth of organic horizons after fire will be further evaluated based on information from *Task D4*. In DOS-DVM-TEM, the representation of C and N biogeochemical processes and pools in the EcoM has been replaced by the representation in DVM-TEM. The DVM-TEM includes interactions among soil thermal dynamics, multiple vegetation pools (leaf, wood, and roots), and a dynamic vegetation component (TEM-DVM) that includes competition for light and N among plant functional types (56-58) (Fig. 36). The coupling of DOS-TEM with DVM-TEM now allows the model to consider competition for water, light, and N in the context of a dynamic organic soil that can be altered by fire disturbance and post-fire vegetation recovery. The ability of DOS-DVM-TEM to simulate successional changes in plant functional types and in associated C and N dynamics after fire will be evaluated by information from the *D3, D4* and *D5*.

We will also use an Alaska peatland version of the methane dynamics module of TEM (MDM) to estimate the exchange of CH_4 with the atmosphere of both wetlands, which generally emit CH_4 to the atmosphere, and uplands, which generally consume CH_4 from the atmosphere. MDM considers the effects of a number of factors on its simulations of CH_4 dynamics including the area of wetlands, fluctuations in the water table of wetlands, temperature, and labile C inputs into the soil solution derived from NPP estimates of TEM. Parameterization of MDM will be based on CH_4 measurements made in upland boreal forest (*Task D6*), upland boreal tundra (*Task D7*), and boreal wetlands (*Task D8*).The previous versions of MDM and its applications and parameterizations for both upland and wetland ecosystems are documented (239-241).

Task CF1 (i.e., task 1 of the climate feedback section): Couple the model of fire regime with the model of ecosystem structure and function, incorporate information developed from Hypotheses 1 and 2 into the coupled model framework, and conduct a retrospective analysis of the coupled model framework.

Overview of Model Coupling

In the modeling framework, the DOS-DVM-TEM and ALFRESCO components will exchange spatially explicit 1 km^2 maps at an annual time step (Fig. 37). For a given year, the spatially explicit fire perimeters will be simulated by ALFRESCO as a function of both climate and vegetation type. Flammability in ALFRESCO will be modified by information provided by DOS-DVM-TEM regarding vegetation biomass and organic matter from the previous year. In addition to simulating area burned, ALFRESCO will simulate burn severity based on information from *Task C5*. Using the characterization of burn severity/succession from *Tasks D1-D3*, the successional trajectory for the post-fire vegetation will then be classified. The linkage between burn severity and post-fire successional pathway will be quantitatively characterized using statistical models. For each year, once ALFRESCO has simulated the fire perimeters and burn severity patterns within the fires, a spatially explicit map of tree seedling establishment within fire perimeters will be passed to DOS-DVM-TEM, which will simulate biogeochemical processes for that year based on information from *Task D4*. At the end of the year, information regarding the vegetation biomass and organic matter thickness will be passed back to ALFRESCO in the form of a spatially explicit map. This information will be used to characterize better the flammability function in ALFRESCO for the subsequent year. The information from DOS-DVM-TEM regarding vegetation biomass will influence flammability, and information on the organic matter thickness will modify burn severity.

Retrospective Evaluation of the Modeling Framework

We will apply the modeling framework to estimate aspects of the historical fire regime and subsequent vegetation recovery from 1860-2010 in interior Alaska (essentially the Yukon River Drainage Basin west of the Alaska-Canada border) at 1 km^2 resolution. Aspects of the model simulation to be evaluated include area burned, fire size distribution, the composition and distribution of vegetation types, stand-age distribution, and the spatial distribution or soil organic matter in interior Alaska. Area burned of the model simulation will be compared with two data sets. The first, which spans 1950-2010, is derived from the Alaska Large Fire Database (110). The second data set, spanning the period 1860-1949 is derived from a modified version of a statistical model (53). The simulation of the composition and distribution of vegetation types will be compared with the 2001 landcover in interior Alaska obtained from the National Land Cover Database (http://www.mrlc.gov/index.php) and with other landcover datasets after 2005 as they become available. A key analysis in this comparison is to evaluate the ratio of coniferous to deciduous vegetation across the landscape, which is an integrated metric of the ability to simulate both fire disturbance and succession dynamics through time. Stand-age distribution will be evaluated with data from available forest inventory surveys in interior Alaska. Finally, we will compare the distribution of organic matter near the end of the simulation to that estimated by a spatially explicit empirical model currently being developed by a postdoctoral researcher in McGuire's lab as part of the USGS project "Assessing the role of deep soil C in interior Alaska: Data, models, and spatial/temporal dynamics", which is synthesizing all of the available information on soil C in interior Alaska into an accessible data base as a pilot project for the National Soil C Network.

Task CF2: Apply the coupled model for future scenarios of climate for interior Alaska and analyze changes in ecosystem function/structure at the regional scale. The coupled modeling framework will be applied to downscaled scenarios of future climate from 2011 to 2100 developed by University of Alaska's Scenarios Network for Alaska Planning (SNAP) program (http://www.snap.uaf.edu/gis-maps) based on the scenarios of the 4th assessment report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). The IPCC AR4 provides output from a suite of GCMs that can be driven by trace gas emission scenarios (148) to produce spatially-explicit representations of climate (196). Individual model scenario performance was evaluated based on model performance for the historical period

1958-2000 (216) and the five best performing models were selected. SNAP scaled down these coarse GCM outputs with a statistical approach using PRISM (http://www.prism.oregonstate.edu/) data, which accounts for variations in slope, aspect, elevation, and coastal proximity coupled with data from nearby weather stations (http://www.snap.uaf.edu/downloads/validating-snap-climate-models). SNAP data are currently available at 2 km resolution, but a new downscaling iteration based on updated PRISM climatology (1971-2000) and a refined 0.8 km resolution will be completed May 2010; for this project we will process these 0.8 km data to 1 km resolution. Using these downscaled GCM scenarios, SNAP now has spatially explicit data of mean monthly temperature and precipitation projections for three different emissions scenarios, including the A2 scenario, which predicts rapid and unchecked increases in anthropogenic greenhouse gas emissions, the B1 scenario, which predicts swift leveling followed by significant decline of emissions, and the A1B scenario, which falls between the other two. In addition, we will use cloud cover data from the Climate Research Unit (CRU; www.ipcc-data.org) for the historical period and develop future data sets of cloud cover for use in the project using appropriate aspects of the SNAP downscaling methodology. These spatially explicit data layers will be used to drive the coupled model framework, which will generate spatially explicit maps of fire, fire severity, vegetation dynamics, albedo (see *Task CF3* below), and C dynamics (including methane exchange, see *Task CF4* below) through time. For this task, we will primarily analyze changes in the distribution of plant functional types in response to future climate change, specifically focusing on changes in the ratio of coniferous to deciduous vegetation across the landscape.

Hypothesis 3b: The responses of water and energy exchange associated with changes in climate and disturbance frequency and severity throughout the 21st Century will result in 1) positive feedbacks to climate warming during the shoulder seasons, and 2) negative climate feedbacks during summer, with net positive feedbacks over the annual cycle.

Question 2: How will projections of regional ecosystem dynamics affect regional energy and water feedbacks to the climate system?

Task CF3: Analyze water and energy feedbacks among the applications of the model to future change in climate for interior Alaska. We have developed a methodology to compute changes in atmospheric heating due to changes in post-fire vegetation and snow cover (56-58, 60). This methodology takes into account information pertaining to latent heat, sensible heat, short- and long-wave radiation as well as information pertaining to vegetation cover for a given year. We will use the vegetation maps and number of years post fire simulated by the modeling framework from the simulations conducted under *Task CF2* of Hypothesis 3a, as well as solar radiation information (based on cloudiness) to estimate atmospheric heating for the years 2010 – 2100 for the SNAP scenarios. Both remotely-sensed and field-based estimates of albedo will be used in our analyses.

Hypothesis 3c: Boreal ecosystems of interior Alaska will lose C as CO_2 to the atmosphere as a result of increased disturbance frequency and severity and increased decomposition because of permafrost thaw, with the response to disturbance dominating the overall flux. CH_4 emissions of boreal wetlands will change because of warming-induced increases in methanogenesis and drainage-induced decreases in methanogensis, with the former response dominating the overall flux.

Question 3: How will projections of regional ecosystem dynamics affect regional CO_2 and CH_4 feedbacks to the climate system?

Task CF4: Conduct factorial experiments with the modeling framework for future scenarios of climate change in interior Alaska to evaluate the relative effects of climate and disturbance on estimates of CO_2 and CH_4. The parameterizations of the plant functional types and soil dynamics of DOS-DVM-TEM and MDM-TEM will be based on studies that have been and are being conducted in interior Alaska. Specifically, we will develop parameterizations of black spruce for different landscape drainage positions based on information from *Tasks C1* through *C3* and *Tasks D3* through *D5*. Other dominant plant functional groups in uplands and floodplains will be parameterized based on information from *Tasks C2* and *C3*. Parameterization of wetland plant functional types as well as CH_4

dynamics will be developed using information derived from APEX (see *Task D8* of Hypothesis 2b). The APEX study has already provided insights concerning CH_4 and CO_2 exchange to water table manipulation (44, 205) for rich fens, and new information from the APEX study will provide insights on these exchanges for intact and thermokarst bogs. The application of DOS-DVM-TEM and MDM-TEM with these parameterizations in *Tasks CF1* and *CF2* above will provide spatially and temporally explicit estimates of CH_4 and CO_2 exchange through 2100 for the full suite of variables used to drive those simulations. To quantify the effects of the various controlling factors considered in this study on terrestrial C dynamics across the Alaska portion of the Yukon River Basin, we will conduct eight model simulations in a fully crossed experiment with three factors: static vs. transient CO_2, static vs. transient climate, and no vs. transient fire. We will determine effects of each factor by subtracting the C stocks of one simulation without the factor (e.g., with static atmospheric CO_2) from another simulation with the factor (e.g., with transient atmospheric CO_2). This will allow us to evaluate main factor effects as well as interactions.

IV. Coupled Social-Ecological Dynamics for Interior Alaska

Our study of coupled social-ecological dynamics will examine the resilience, adaptation, and transformation of interior Alaska, with a focus on the sustainability of rural Alaska Native villages. Although the majority of people in Alaska live in a few urban centers, rural villages constitute a key network underpinning Alaskan culture and are likely to be most sensitive to ongoing environmental changes. Moose, caribou, and berries are keystone subsistence resources for villagers (31, 152) that serve to integrate our social-ecological research. To complete our integration successfully requires that social and natural scientists work collaboratively to make linkages of ecological change, social responses, and their respective feedbacks explicit, and directly relate their work to the ISSE framework (Fig. 17). Through this effort we also establish a BNZ team of scientists, including an economist, sociologist, policy scientist, and anthropologist, who will work collaboratively with natural scientists of the BNZ LTER to understand social-ecological dynamics. This research group will also build partnerships with stakeholder groups of rural and urban interior Alaska for the co-production of knowledge concerning change and exploration of options for human adaptation.

The social-ecological system of interior Alaska is unique in composition, including one large urban area (Fairbanks and area – population ~70,000), several regional centers (e.g., Fort Yukon – population ~600) and many small rural villages (populations of ~300 to <20), with most villages being off the road system and indigenous in cultural orientation. Small villages are highly dependent on ecosystem services through hunting, fishing, and gathering as part of a traditional subsistence-cash economy. On-the-land traditions and experience are the basis for rich local knowledge of land, resources, and social-ecological change, offering the opportunity for research-community partnerships. Today's demographic and economic conditions in villages and Alaska as a whole set up interdependences and conflicts with urban residents, who are in many cases in competition for ecosystem services, such as in the harvest of moose, caribou, and some fish resources. The signals of climate warming, such as increased fire frequency and drying, add pressure to rural-urban dynamics (Fig. 38). Finally, the conditions of persistent poverty in villages raise questions about the high dependence on ecosystem services and government support, and thus the question of long-term sustainability of communities in the face of rapid change. Below we describe three questions with tasks that are undertaken as a part of research that orients BNZ LTER studies in a social-ecological framework. As outlined below, many of these tasks that are a part of this element are undertaken collaboratively with complementary projects already funded.

Question 1: How is climate variability and change affecting the capacity of boreal forests to supply provisioning and cultural ecosystem services to Alaskans?

Task SE1 (i.e., task 1 of the social-ecological dynamics section): Identify the suite of services most critical to sustainability in interior Alaska. Previously funded research at UAF has assessed, compiled, and evaluated available data on urban and rural moose harvesting, making broad comparisons between urban and rural harvest levels, hunting access methods, and use areas. More compilation of quantitative data is needed to assess levels of use and dependence on the critical set of ecosystem services by rural villagers and urban residents. For example, time series data on harvesting of big game are currently collected by government agencies for urban hunters, but are incomplete for most rural villages because of lack of participation by Alaska Native hunters in the state's wildlife management reporting system. Moreover, there are limited data on harvesting of non-market forest products, such as berries, that are gathered both by villagers and urban residents. Some data are available, however, for villages through the Alaska State Fish and Game Division of Subsistence, tribal resource management agencies, and university research (Fig. 39). The ecosystem services provided to and utilized by villages can be represented in "seasonal rounds" of harvesting (i.e. taking moose in the fall, caribou in the fall and winter, ducks in the spring, fish and berries in the summer) (Fig. 40). We will build a metadata base of ecosystem services, construct seasonal round representations of village harvesting for a set of interior Alaskan villages of different types, and identify the most critical suite of ecosystem services for villages and residents of the Fairbanks area. These data will be used to assess the level of heterogeneity of interior Alaska's social-ecological systems and thus provide an important input for the social-ecological research on change described below.

Task SE2: Identify past trajectories and rates of change and likely future changes in critical ecosystem services. Task SE2 builds on and integrates on-going LTER research and other initiatives to document change. LTER ecological research examining changes in snow conditions, forage for moose, fire frequency, predation, and moose population dynamics all contribute to the study of changing ecosystem services. As part of task SE2, we partner with the Arctic Borderlands Ecological Knowledge Coop, a community-based ecological monitoring network started in 1995 involving several interior Alaskan villages and the Western Canadian Arctic (http://www.taiga.net/coop/index.html). The Coop monitoring program documents local observations of change annually to provide an understanding of ecosystem dynamics through a local and cultural lens. The program's ten-year summary of findings revealed local perceptions of local-scale processes, identified data gaps, and generated alternative hypotheses potentially worthy of systematic empirical scientific research (47). The use of local knowledge in ecological monitoring raised methodological issues of integrating local knowledge with western science in long-term ecological research. In this proposal, the BNZ LTER will expand the program by funding an additional Alaskan interior village in Borderlands Coop monitoring. Interviews for community monitoring are completed annually by local indigenous research associates. The findings from interviews will be reported back to BNZ scientists annually at a UAF seminar to stimulate discussions about local and scientific understandings of change at the local-to-regional scales. LTER researchers will also participate in the Borderlands Coop annual gatherings of participating communities and program collaborators.

BNZ LTER biophysical research and community ecological monitoring complement the MAPS and LOCALS (MALS) project of the LTER Network, funded in 2009 through the LTER Social Science Supplement and led by the BNZ LTER. MALS integrates qualitative local knowledge about change with a quantitative time-series spatial analysis of land-surface change. MALS is a collaborative project of 11 LTER sites (http://www.lter.uaf.edu/bnz_MALS.cfm), which uses comparative network-wide study to put the research into a network-wide context. Since the ARC LTER is also involved in MALS, we compare land-surface changes and local knowledge in two regions of Alaska. The scenarios of SNAP (see *Section III*) have generated outputs on projected future changes in bio-physical processes. In our social-ecological analysis, SNAP scenarios move the BNZ MALS project from a retrospective to a prospective assessment of change, with projected changes serving as the basis for discussions with subsistence experts and leaders of villages to document if and how local knowledge compares with synthetic modeled knowledge of ecological change. The goal of *Task SE2* is not to prove one knowledge system wrong and the other correct, but to improve LTER research through learning among researchers and community residents, and generating research objectives that are of interest to all.

Question 2: How do changes in ecosystem services affect community resilience in interior Alaska?

Task SE3: Model the interaction of ecological, economic, cultural, and demographic conditions affecting participation in subsistence in rural households of interior Alaska, and how those dynamics affect village sustainability. Making the link between changes in ecosystem services and human livelihoods in interior Alaska requires an in-depth understanding of the interactions of both ecological systems and social variables, including village cash economics, village and urban demographics, the strength of ties in resource sharing networks among village households, and levels of participation by individuals in the subsistence economy (Fig. 41). For example, village residents report that the recent increase in fuel costs has affected the availability of key subsistence resources by raising the cost of fueling snowmobiles and boats for hunting and for transporting freight to villages. Changes in transportation costs increase the cost of purchasing snowmobiles, boat motors, or four wheelers, and shipping store-bought foods to villages. The combination of climate change, which is in some cases negatively affecting ecosystem services, and economic change, such as changes in fuel cost, leads to a greater perceived food insecurity. Demographic data suggest that in some small villages, population levels may be approaching a tipping point as families increasingly migrate to urban centers in search of jobs. The work of *Task SE3* is to assemble documented local knowledge and social scientific data, and combine findings concerning patterns of change with projections on ecosystem services gathered in *Tasks SE1* and *SE2*, such as those generated by ALFRESCO. We seek to move from anecdotal accounts, as presented above, to quantitatively modeled relationships that allow for validation and simulation. Thus, a key objective of our integrated modeling is identifying critical social-ecological tipping points and potential regime shifts of the social-ecological system. Construction of the model is undertaken in cooperation with “Modeling harvesting behavior to understand adaptation, mitigation, and transformation in northern subsistence systems” (NSF-Kofinas, PI), which provides a modeler and a graduate student.

Task SE4: Conduct institutional analysis to identify the role of policy in mediating the effects of changing ecosystem services. Institutional arrangements shape human choices in responding to change and therefore affect the role of human agency in the adaptation process. Institutional arrangements shaping village responses to change are both formal and informal, with formal institutions including government regulations, such as the procedures that govern allocation decisions on the harvesting of subsistence resources, policies on predator control, and fire management. Informal institutions include sharing networks, such as traditional indigenous obligations to distribute harvested subsistence resources among village households. Many choices in an adaptation process require an evaluation of trade offs, with some trade offs emerging from ecological conditions, others from socio-economic conditions, and others from the interaction of the two. *Task SE4* is aimed at identifying the most critical institutions (i.e., formal and informal policies) that enhance and constrain community capacity to respond to change, and evaluating the need for institutional adaptations and transformations to achieve community sustainability. Through a project funded by the Mineral Management Services, we are documenting social networks of subsistence sharing at the household level, an important source of resilience for households and villages. Here we combine that study of informal sharing institutions to understand more clearly their interactions with formal policy. The institutional analysis informs the modeling described in *Task SE3* and is undertaken with a participatory approach involving local communities. Our approach to community participation is described below.

Question 3: What are the opportunities of human adaptation and transformation in the face of rapid changes to interior Alaskan social-ecological systems?

Task SE5: Through partnerships with communities, identify conditions that facilitate innovation in future human adaptation and transformation. In addition to completing *Tasks SE1* to *SE4* in consultation with local residents of villages, we will convene the BNZ LTER Community Resilience Working Group, composed of 6 village leaders who will gather annually to review BNZ LTER research findings and discuss opportunities for community adaptation and transformation. This approach to community involvement in LTER research builds on our past experience of bringing researchers to Venetie, Alaska in 2009 where academics and local harvesters shared their perceptions of ecological and social change, discussed the policy dimensions of these changes, and together explored ways of understanding problems better and resolving those problems. Here we propose a set of meetings that provide an important sounding board for the LTER to situate its work in a local context. As a part of this process, working group members will review scientific research findings where appropriate, use the model of *Task SE3* as a discussion tool, study the implications of scenarios of possible futures, and consider the policy dimensions of change. When possible, meetings of the working group will take place in villages to broaden our interaction with the greater public.

Summary

The research described in this proposal and summarized in Table 3 represents an integrated framework to study the interactive effects of changing climate and disturbance regimes on the Alaskan boreal forest, and understand the consequences for regional climate feedbacks and implications to social-ecological systems that include subsistence-based communities. Our last funding cycle provided insights into the dynamics of an ecosystem undergoing rapid ecological and social change. We are beginning to understand how climate-driven changes in disturbance regimes are affecting biogeochemical cycling and plant community dynamics to alter successional pathways. We have also made advances on how non-steady-state dynamics (permafrost thaw, watershed N and C loss, insect/pathogen outbreaks, wildfire, vegetation trajectories) are altering landscape structure and hydrology, and affecting trace gas and energy feedbacks to regional and global climate. Our work on the feedbacks that govern social-ecological resilience has provided insights on how residents of rural communities, resource management agencies and policy makers might develop adaptive solutions for the challenge of sustaining rural communities and their subsistence livelihoods. In this proposal, we reorganize our research structure (Fig. 18) with the goal of achieving a more functional understanding of Alaska's boreal forest as a social-ecological system. Specific research tasks are intended to fill critical gaps in our understanding of the ecological and social processes contributing to resilience, and the patterns, mechanisms and consequences of regional change. As well, we generate future scenarios for Alaska' boreal forest system over the next century that inform our science and interactions with stakeholders. Our research includes on-going and new studies and long-term experiments that inform retrospective and prospective modeling of the regional system. This research is supported by a monitoring program redesigned to focus on changing successional trajectories. We are actively involved with K-12 students and educators, interact and collaborate with personnel from state and federal agencies within Alaska, partner with Indigenous Peoples of the region, and enthusiastically continue our recently-developed outreach program to the Fairbanks arts and humanities community (see Section 5 below).

We expect synthesis activities to play a central role in the program, through modeling, monthly meetings focused on tasks within each section, and annual meetings focused on synthesizing findings within individual proposal sections. This approach has proven highly successful during the current funding cycle and resulted in a number of synthesis products; however, we seek to improve on the annual meetings by emphasizing linkages among sections and adding a day of synthesis workshops dedicated to social-ecological dynamics. During year 3, we plan to host a joint meeting with the ARC LTER focused on resilience and transformation in high latitude systems. Changes in climate-disturbance interactions are impacting these biomes in different ways, but as woody plants and disturbance regimes move northward, we are well poised to explore more carefully the linkages of these two programs.

From past experience we are confident that the breadth of our proposed activity is feasible. Our strategy is to establish an integrative framework for boreal research, involve a group of highly qualified researchers who work well together, and encourage them to link other funded research projects to the LTER framework. This externally funded research of LTER investigators focuses on detailed process studies, modeling, and social-ecological systems that are beyond the scope of LTER funding capabilities (See Table 8 in Budget Justification for listing of projects). We also plan to situate our results within a global context through synthesis of data from other boreal regions and involvement in cross-site activities within the LTER network (Table 4), especially those dealing with changes in climate and disturbance regimes, non-steady-state dynamics, and social-ecological systems. The BNZ and ARC LTERs represent one end of a spectrum of current social-ecological change. Comparisons of social-ecological systems across the spectrum of human population densities and impacts will provide valuable insights about how human activities influence the resilience of social-ecological systems.

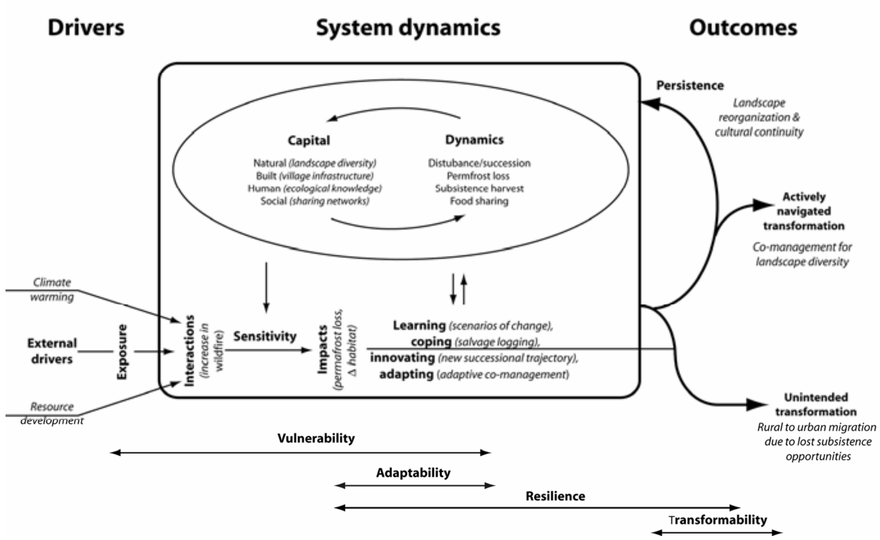


Fig.1. System perspective on the vulnerability and resilience of the AK boreal forest. External stresses interact to increase the extent and severity of wildfire, creating impacts (permafrost loss and habitat change). Social learning (learning, coping, innovating, and adapting) in response to these impacts has the potential to alter social-ecological interactions and various forms of capital of the system, which in turn influence sensitivity to future events. Social learning also governs the likelihood of 3 potential outcomes: persistence through resilience; actively navigated transformation to a new, potentially more beneficial trajectory through transformation; or unintended degradation to a new state due to vulnerability and failure to adapt or transform (Chapin et al. in press).

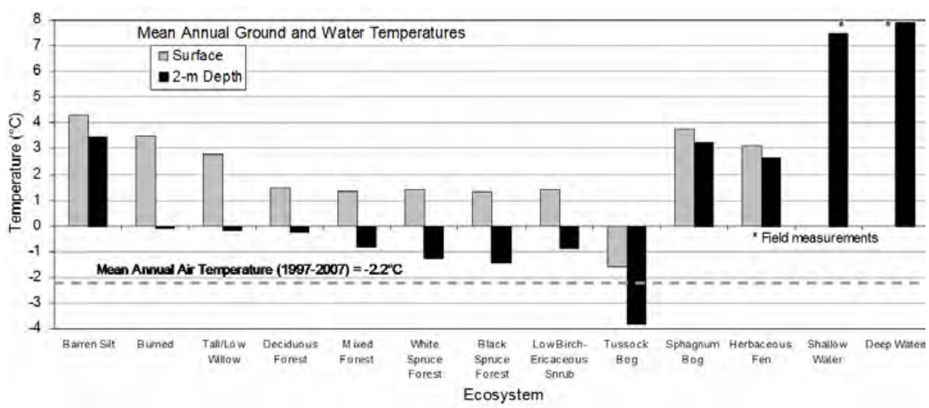


Fig. 2. Modeled mean annual temperatures at the surface and at 2-m depth for common boreal ecosystems in central Alaska. Mean annual temperatures for shallow and deep waterbodies were measured in Denali NP; actual measurements were used for waterbodies because soil thermal modeling is not appropriate for water (Jorgenson et al. in press).

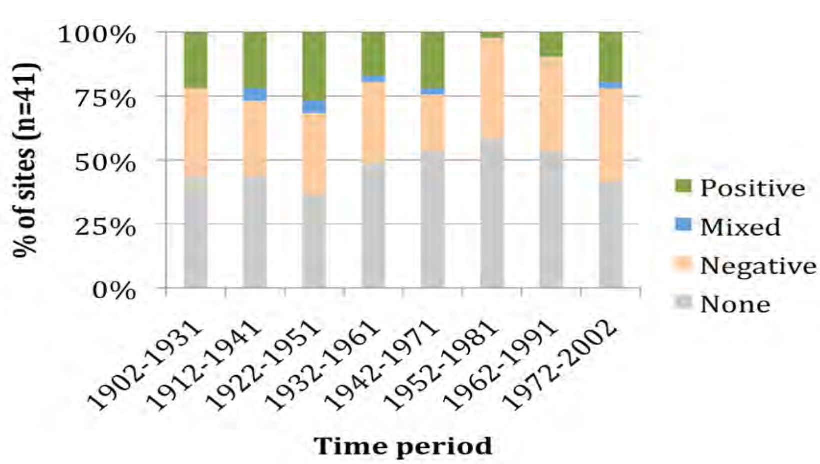


Fig. 3. Proportion of white spruce sites (n=41) exhibiting different responses to temperature: positive (>2/3 of significant correlations with temperature are positive), negative (>2/3 of significant correlations with temperature are negative), mixed (1/3 to 2/3 of significant correlations are positive), or none (no significant correlations with temperature) (McGuire et al. in press).

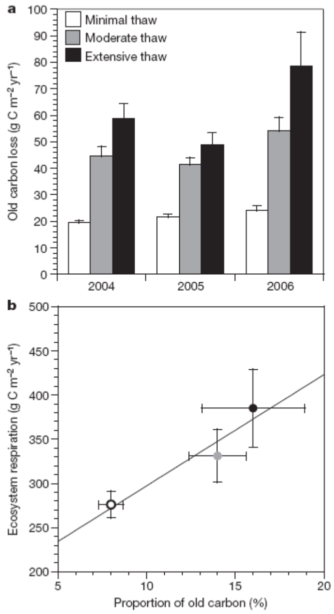


Fig. 4. Old C loss and its relationship to total ecosystem respiration for three sites that differ in the extent of permafrost thaw. (a) Growing-season loss of old C from deeper in the soil profile, (b) Relationship between total ecosystem respiration and proportional old C loss for the growing season across sites (Schuur et al. 2009).

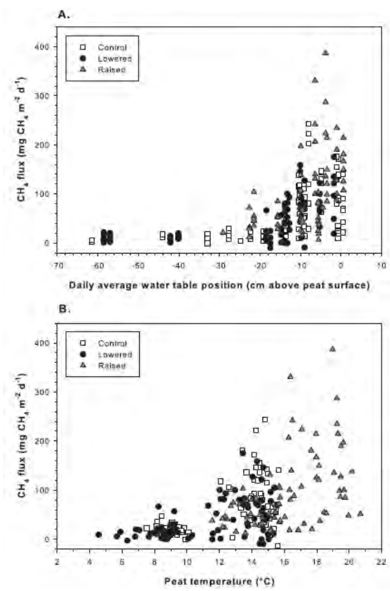


Fig. 5. Effect of water table position (A) and peat temperature at 25 cm depth beneath the moss surface (B) on CH_4 fluxes across the three water table treatments (Turetsky et al. 2008).

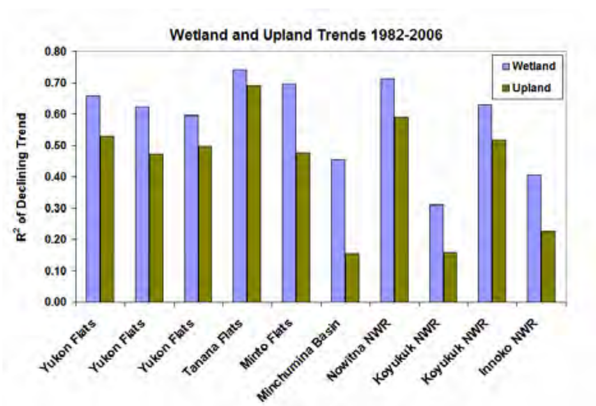


Fig 6. Rate of lake drying at 10 locations throughout interior Alaska showing greater rates of decline in wetland vs. upland landscapes (redrawn from Riorden et al. 2006).

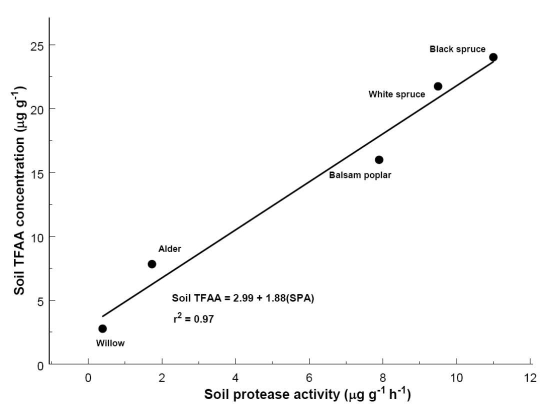


Fig. 7. Relationship between soil protease activity and soil total free amino acid (TFAA) concentrations across successional soils on the Tanana River floodplain, interior Alaska (Kielland et al. 2007).

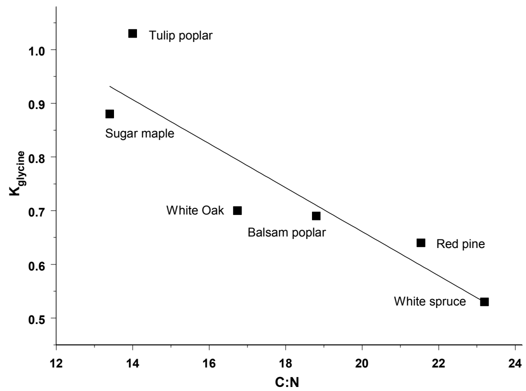
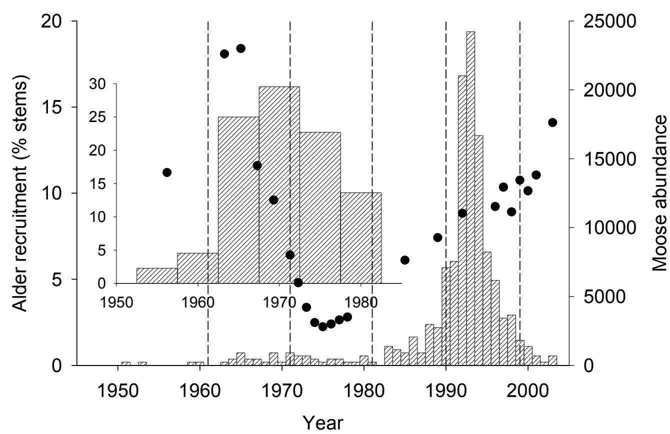


Fig. 8. Relationship between *in situ* glycine mineralization ($k_{glycine}$) and soil C:N from a cross-site study comparing boreal and temperate forest amino acid cycling dynamics (McFarland et al. in press). Across sites, *in situ* glycine turnover was better explained by changes in soil C availability than variation in soil temperature or concentrations of DIN and FAA-N, suggesting the consumption of these low-molecular-weight substrates by soil microorganisms may be governed as much by the overall decomposability of soil C as by N limitation to microbial growth.

Fig. 9. Alder recruitment (bars), abundance of moose (dots), and snowshoe hare peaks (dashed lines) at the landscape scale. Two waves of alder recruitment were identified. The inset shows alder recruitment data only from 1950-1985, scaled by 5-year age classes, while the larger graph extends from 1950-2005 and is scaled by 1-year age classes (Nossov et al. submitted).



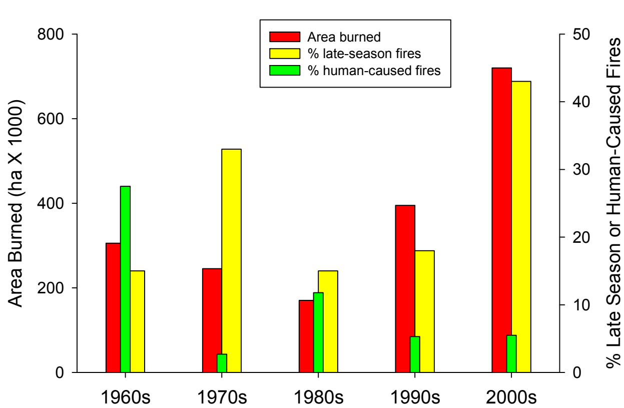


Fig. 10. Characteristics of the Alaska fire regime over the past 5 decades (drawn from Kasischke et al. in press).

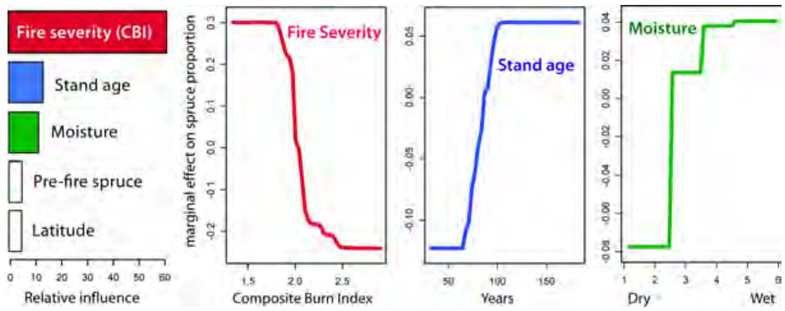


Fig. 11. Results of a boosted regression tree model predicting the relative dominance of black spruce vs. deciduous trees in early post-fire communities following the 2004 fires (n=78). The bar chart shows the relative influence of different variables in the model. Line charts are partial dependency plots representing the estimated marginal effect of the three most important variables on *y* when all other variables are held at their average. Results are presented for the simplest model that minimized prediction error (final prediction error of 42%) (redrawn from Johnstone et al., in press).

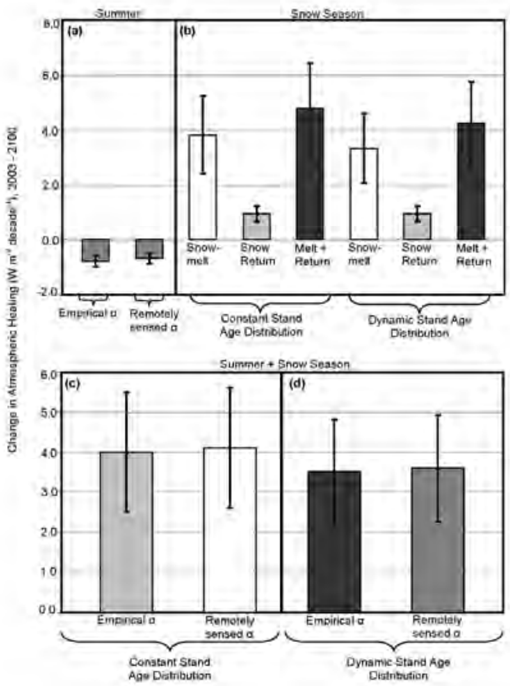


Fig 12. Mean changes in atmospheric heating from 2003 - 2100 across all four input climate scenarios (W m^2 decade^{-1}, ± standard deviation). In (a), the changes in atmospheric heating are due to summer albedo change based on both empirical and remotely sensed estimates of albedo (α). In (b), the changes in atmospheric heating are due to the snow season albedo changes, taking into account both a constant forest stand age distribution and a dynamic forest stand age distribution. In (c), the changes in atmospheric heating for the summer and snow season are summed and are based on the constant forest stand age distribution for the snow season. In (d), the changes in atmospheric heating for the summer and snow season are summed and incorporate the dynamic stand age distributions for the snow season (Euskirchen et al. in press).

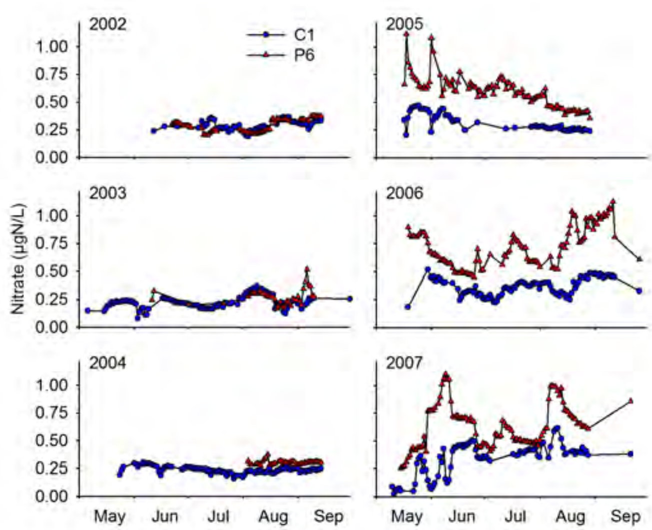


Fig. 13. Pre- and post-fire NO_3^- concentration (ppm) in burned (P6) and control (C1) catchments of Caribou-Poker Creeks Research Watershed for 2002 – 2007. The Boundary Fire burned through P6 in July of 2004 (Betts and Jones, in press).

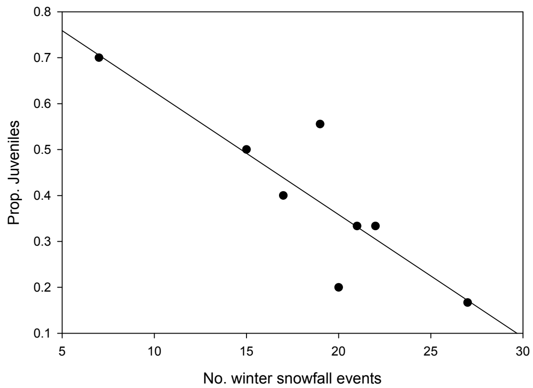


Fig. 14. Proportion of juvenile snowshoe hares in the population during late winter in relation to frequency of over-winter snow fall events 1999-2008 (Kielland et al. in press).

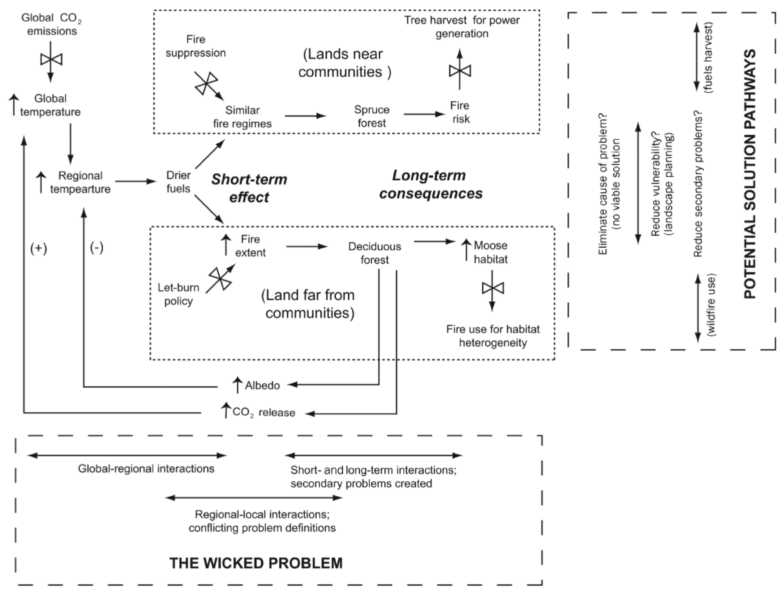


Fig 15. Model of the interactive effects of climate change and fire suppression on short- and long-term fire risk in interior Alaska, identifying the interactions that generate wicked problems (horizontal arrows at the bottom of the diagram) and selected pathways to potential solutions (vertical arrows at the right of the diagram). Bowties show points of potential policy intervention (Chapin et al. 2008).

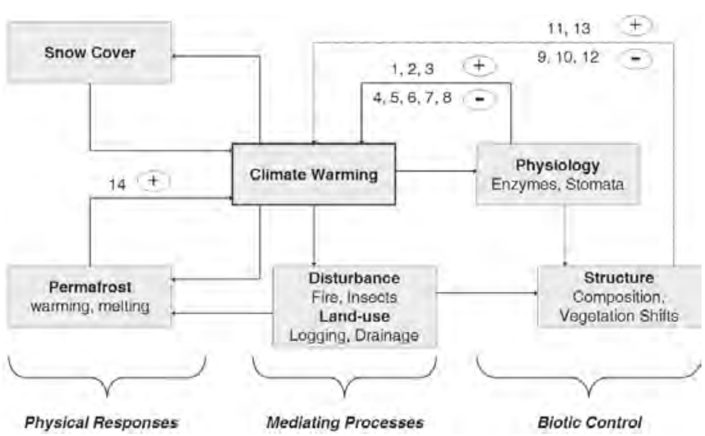


Fig. 16. Terrestrial carbon responses to warming that influence the climate system. Physical responses of snow cover and permafrost are coupled with functional (physiological) and structural biotic responses. *Physiological feedbacks* designated on the diagram are (1) increased decomposition of soil organic matter (CO2↑), (2) vegetation productivity (NPP) response to drought stress (CO2↑), (3) methanogenisis response to increasing temperature and soil moisture (CH4↑), (4) methanogenisis response to drying (CH4↓), (5) NPP response to longer growing season (CO2↓), (6) NPP response to increased N mineralization (CO2↓), (7) NPP response to temperature increase (CO2↓), and (8) NPP response to increased atmospheric CO2 concentration (CO2↓). The *structural feedbacks* shown are (9) expanded distribution of tundra shrubs (CO2↓), (10) treeline advance (CO2↓), (11) forest degradation (CO2↑), (12) conversion of light to dark taiga (CO2↓), and (13) increased occurrence of fire, insects, and logging (CO2↑). The physical responses include (14) the release of inorganic carbon from permafrost thaw (CO2↑, CH4↑) (McGuire et al. 2009).

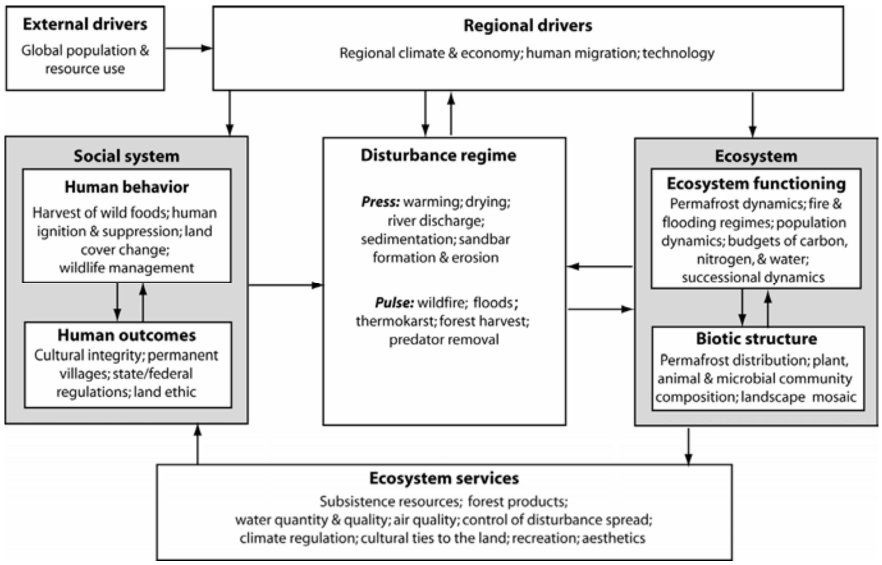


Fig. 17. Diagram of the Alaskan boreal social-ecological system. Global-scale drivers of change influence the regional drivers that directly perturb the boreal system through effects on social and ecological subsystems and the disturbance regime that links these subsystems. The resulting changes in dynamics alter ecosystem services, which modify human behavior and outcomes (Chapin et al. in press).

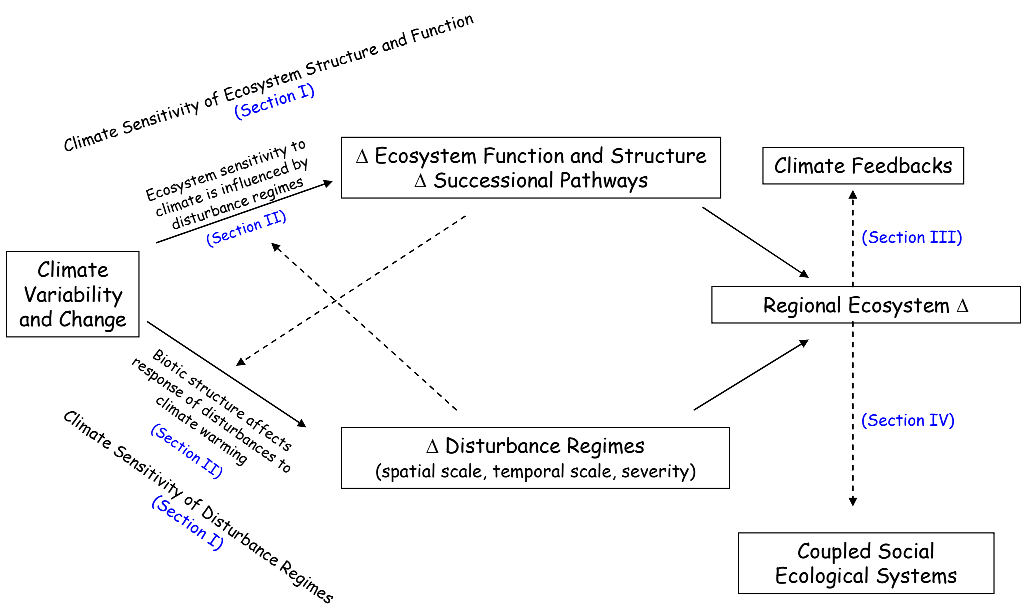


Fig. 18. Conceptual model describing proposal components.

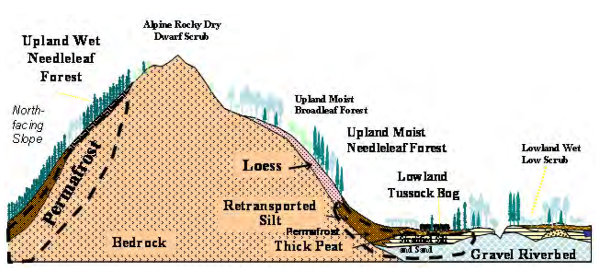


Fig. 19. Schematic of common co-varying ecosystem landscape units across the boreal landscape in interior Alaska (Jorgenson et al. in press).

Table 1. Parameters measured by BNZ LTER monitoring program.

Parameter	**Location**	**Dates**	**Responsible PI**
Climate			
Air & Soil temperature	BCEF, CPCRW	1984-	J. Hollingsworth
RH, Evaporation & Precipitation	BCEF, CPCRW	1984-	J. Hollingsworth
Wind speed & direction	BCEF, CPCRW	1984-	J. Hollingsworth
Solar radiation (global)	BCEF, CPCRW	1984-	J. Hollingsworth
UV, PAR	BCEF, CPCRW	1984-	J. Hollingsworth
Short & Long wave in/out	CPCRW	1988-	J. Hollingsworth
Sun photometer	BCEF,	1994-	J. Hollingsworth
Snow depth & snow moisture	BCEF, CPCRW	1968- 1983-	J. Hollingsworth
Thaw depth	BCEF, CPCRW	1992-	J. Hollingsworth
Permafrost temperature	BCEF, CPCRW†	1980-	Romanovsky, Schuur
Vegetation, Insects, and Animals			
Tree density, biomass	BCEF	1989-	T. Hollingsworth, Ruess
Tree seedling density	BCEF	1989-	T. Hollingsworth, Juday
Understory cover, biomass	BCEF	1989-	T. Hollingsworth
Seed rain	BCEF	1955-	J. Johnstone
Insect defoliators	BCEF	1976-	Wagner, Juday, Werner
Alder canker	BCEF†	2005-	Ruess
Snowshoe hare populations	BCEF	1999-	Kielland
Biogeochemistry			
Carbon and nutrient stocks			
Trees & Understory	BCEF	1989-	Yarie, Ruess
Soils	BCEF	1989-	Mack, Harden
N mineralization	BCEF, CPCRW	1999-	Kielland
Nitrogen deposition (NADP)	CPCRW	1993-	Jones
AGNPP			
Litterfall	BCEF	1975-	Ruess, Yarie
Diameter increment	BCEF	1989-	Ruess, Yarie
Browse consumption	BCEF	1990-(c)	Kielland
Watershed research			
Discharge	CPCRW	1969-	Jones
Stream chemistry	CPCRW	1978-	Jones

†Monitoring network includes sites throughout interior Alaska

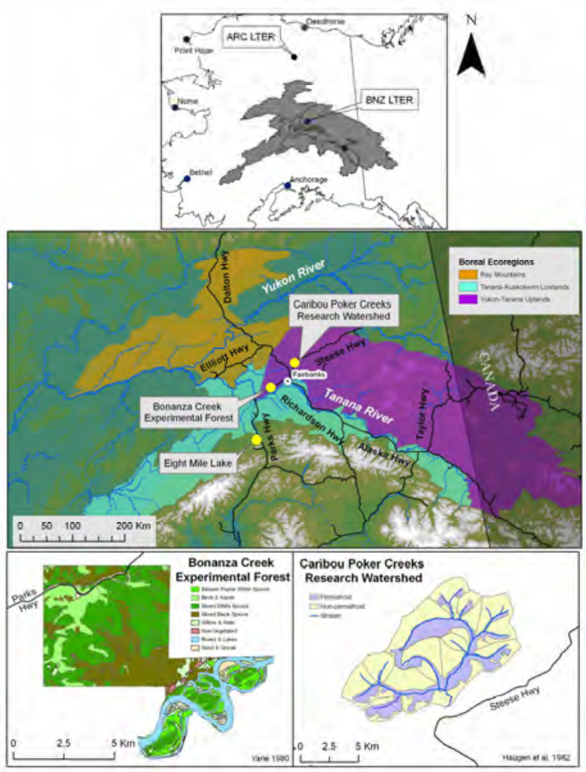
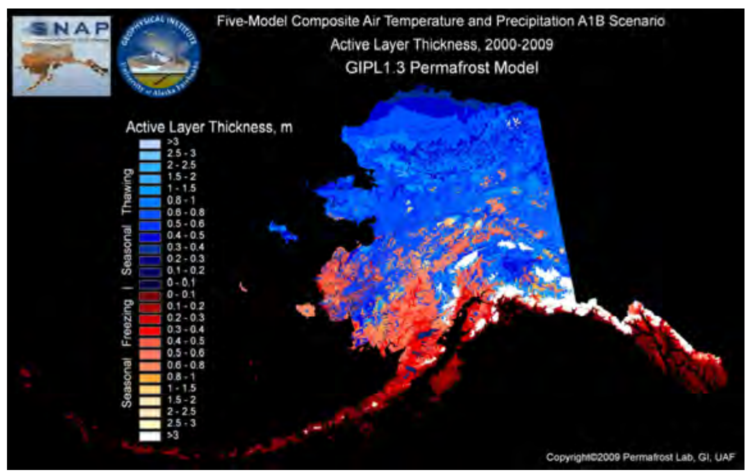


Fig. 20. Hierarchical experimental design of the BNZ LTER, showing current intensive study sites and watersheds at BCEF and CPCRW nested within the 3 ecoregions defining interior Alaska, across which the new BNZ LTER regional site network will be located.

Table 2. Long-term experiments in the BNZ LTER site

BNZ long-term experiments	Responsible PI	Date initiated
Climate manipulations		
Summer precipitation exclusion	Yarie	1989
Spring snow removal	Yarie	2004
Winter snow reduction	Taylor	2004
Snow fence	Schuur	2009
Water table manipulation (APEX)	Turetsky, Harden	2006
Resource manipulations		
Annual N addition	Yarie	1989
Annual N and P addition	Ruess	1997, 2003, 2006
One-time sawdust or sugar addition	Yarie	1989
Root-trenching experiment	Valentine	1999
$^{15}NH_4$ post fire retention	Mack	1999
Monitoring floodplain biogeochemistry	Kielland, Jones	2002
Community manipulations		
Mammalian herbivore exclosures	Kielland	1990
Alder-willow interactions	Ruess	2009
Artificial alder communities	BNZ LTER	1990
Insect population monitoring	Werner, Juday	1976
Snowshoe hare population monitoring	Kielland	1999
Herbivore effects on white spruce	Kielland	2002
Fire effects on soil thaw depth	Hollingsworth	1983
Ecosystem manipulations		
Forest harvest experiments	BNZ LTER	1972
Experimental burn (FROSTFIRE)	Hollingsworth	1999
Monitoring watershed hydrology	Jones	1970

Fig 21. GIPL results from simulation of maximum active layer depth for Alaska for the periods 2000-09.



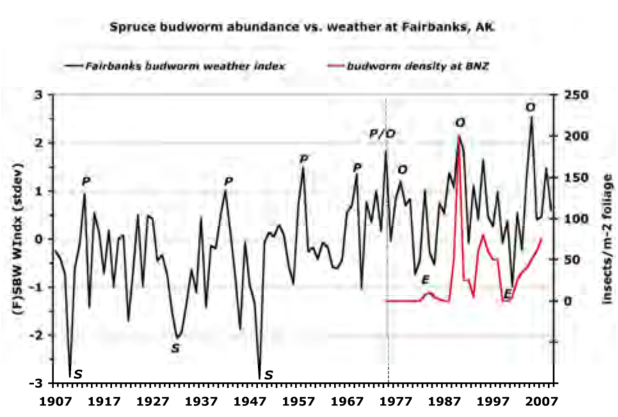
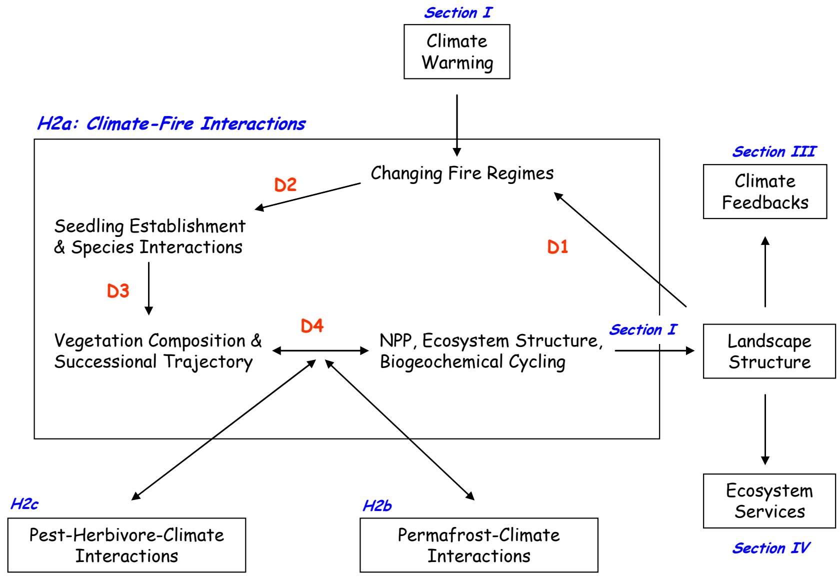


Figure 22. Spruce budworm temperature predictive index at Fairbanks (F-SBW), for the period of weather record, 1907-2007 (black line) and BNZ spruce budworm monitoring data, 1975-2007 (red line). Years of extreme weather with known or potential significant relationship to spruce budworm population status are indicated; P = potentiating (1913, 1942, 1958, 1969, 1975), S = sterilizing (1910, 1932-33, 1949), E = exclusionary (1981-82, 1985, 1999-2000), O = outbreak (1978, 1989-90, 1993&95, 2005-06) (Juday et al. in review).

Fig. 23. Conceptual diagram showing how tasks (notations in red) link components with the section on climate-fire interactions, and how this section is tied to other proposal components.



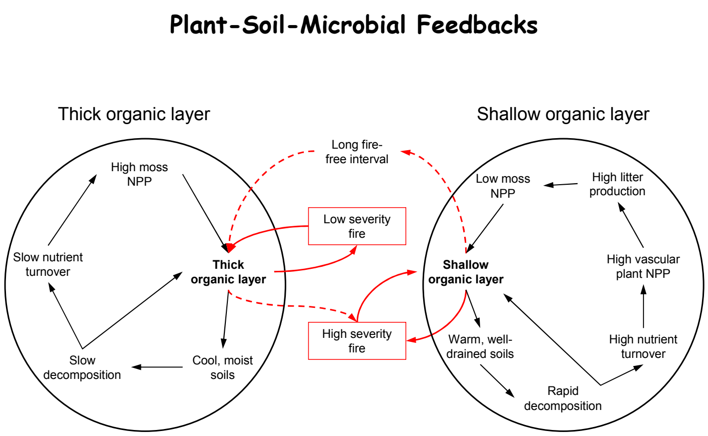
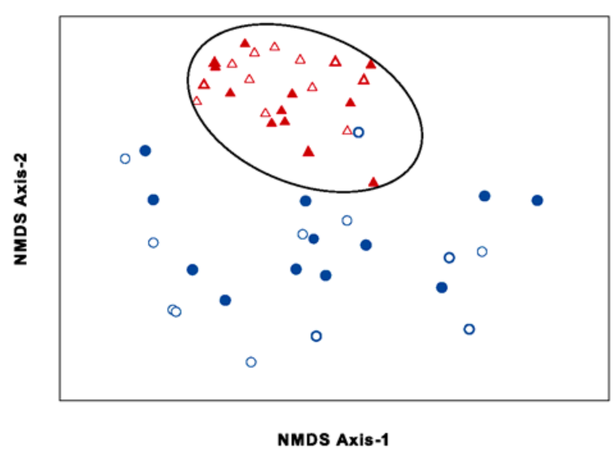


Fig. 24. Cycles of soil organic layer dynamics over successional time. A. The accumulation of soil organic layers in mesic to moist sites is associated with cool, moist soils, low rates of decomposition and nutrient cycling, and high moss productivity (net primary productivity, or NPP). B. Alternatively, shallow organic layers in mesic to dry sites are associated with high warm, dry soils, high rates of decomposition, and high vascular plant productivity that shades out mosses. Shallow organic layers are also maintained at dry sites (thin dotted line) by direct moisture limitation of moss productivity. Typically, fires burn sites with thick organic layers with low severity (low % combustion), which allows soil organic layers to accumulate across fire cycles. Sites with shallow organic layers may burn with high or low severity, but rarely accumulate substantial organic layers across fire cycles. Changes in climate (multi-decadal warming or cooling) or unusual fire events (thick dashed lines) may cause sites to switch from one form of the cycle to another (Johnstone et al. in press).

Figure 25. NMDS ordination of belowground fungal communities associated with mature black spruce stands. 50 soil cores were collected at each site in 2004 and 2005. Composite samples were created for each site-year-horizon (organic, mineral) combination and subject to high throughput PCR clone library sequencing. Fungal communities showed little inter-annual variation, and were thus resilient to climate variability, but were strongly structured by soil horizon (Taylor et al. in press).



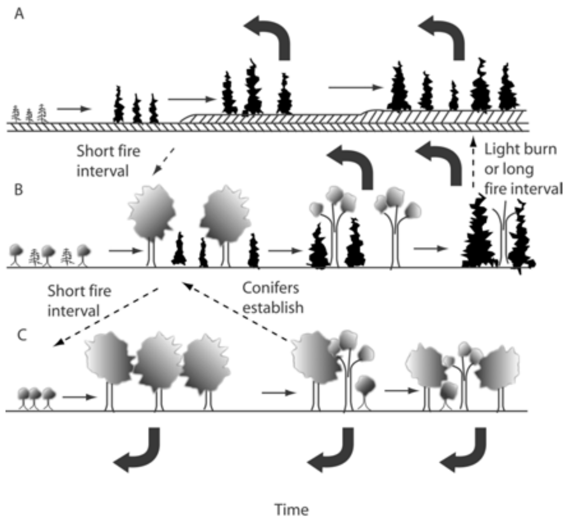


Fig. 26. Three alternative successional trajectories that occur after fire in interior Alaska. Each row shows the temporal change in community composition after postfire recruitment. Thin arrows show the normal successional transitions. Thick arrows show the most likely postfire transition (to an early successional stage of the same successional trajectory). Dashed arrows show events that lead to new successional trajectories. Successional trajectories shown are (*A*) conifer succession, (*B*) relay floristics in which conifers replace deciduous trees, and (*C*) deciduous succession. The hatched ground cover represents an organic mat that prevents establishment of deciduous tree seedlings (Chapin et al. 2004).

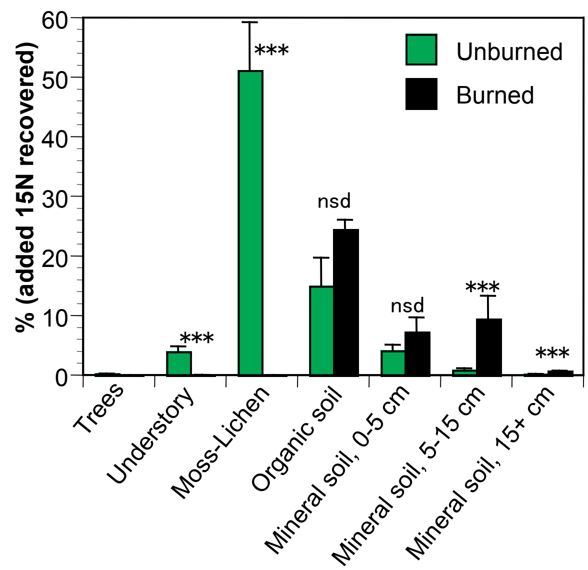


Fig. 27. Results from a ^{15}N labeling experiment showing that 1 year after fire, higher recovery of ^{15}N in unburned stands (80%) was substantially higher than in burned stands (40%) due principally to retention afforded by mosses (Mack, unpublished data).

H2b: Climate-Permafrost Interactions

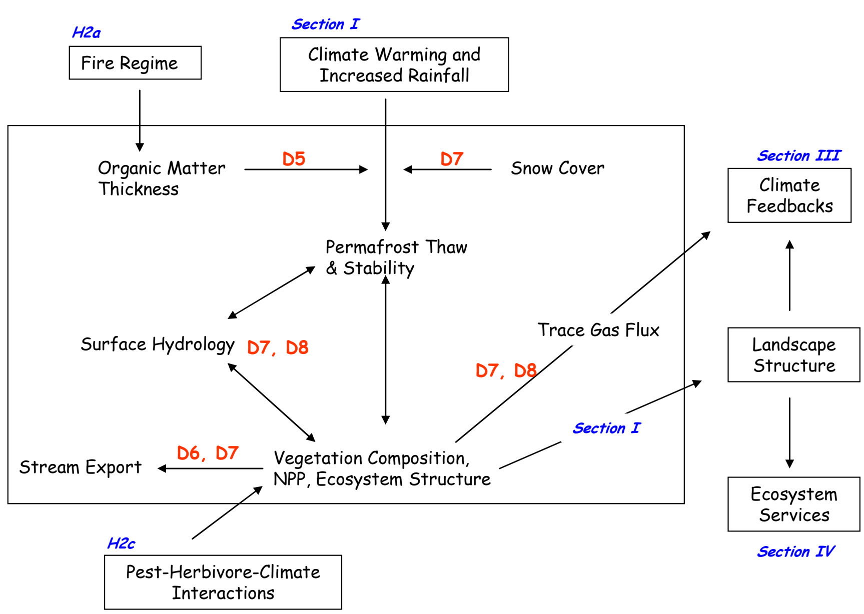


Fig. 28. Conceptual diagram showing how tasks (notations in red) link components with the section on climate-permafrost interactions, and how this section is tied to other proposal components.

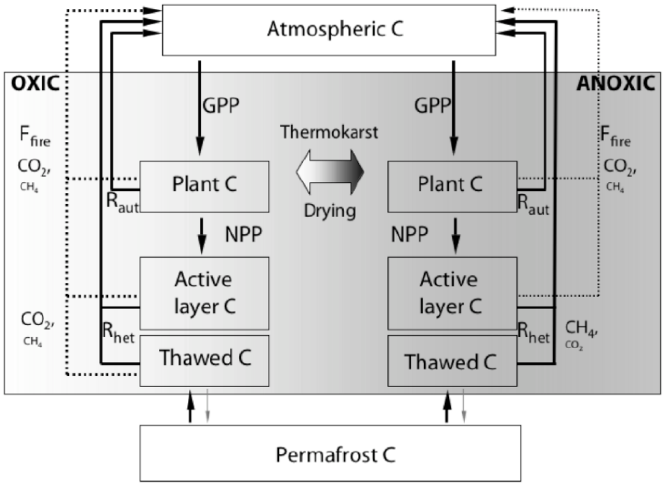


Fig. 29. Depending on underlying conditions, ecosystems can become drier (shrinking lake area, drying wetland/peatlands), or wetter (thermokarst lakes) as permafrost thaws. Soil oxygen status is a key determinant of the rate and form of C loss to the atmosphere as permafrost thaws. Decomposition in oxic soils releases primarily CO_2, whereas anoxic decomposition produces both CH_4 and CO_2, but at a lower total emission rate. Fire releases mostly CO_2, but also some CH_4, and can burn upland and wetland ecosystems, although burning of organic soils at depth is restricted in wetter environments unless there is severe drought. These emissions of C through decomposition are offset by gross and net primary productivity. Under some local conditions, it is possible that C will enter the permafrost pool (grey arrow), although this total amount is small relative to C that is expected to thaw from permafrost as a result of climate change (Schuur et al. 2008).

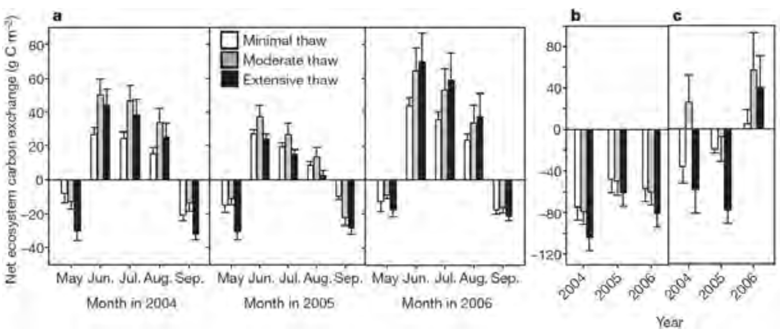


Fig. 30. Net exchange of CO_2 between tundra and the atmosphere for 3 sites that differ in the extent of permafrost thaw. a, For the growing season (May–September); b, for the winter (October–April); and c, on an annual basis. Values represent total C uptake (positive) or release (negative) per month (a), per winter (b) and per year (c) (Schuur et al. 2009).

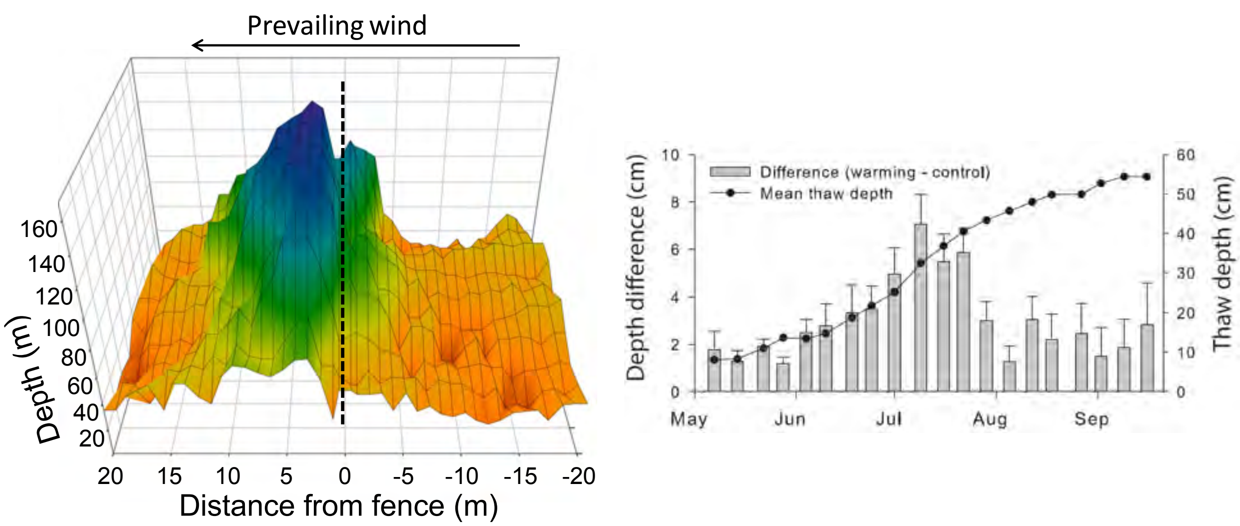


Fig. 31. Permafrost Ecosystem Warming Experiment (at Eight Mile Lake) showing effects of the snow fence on maximum snow depth measured in March 2009 (left) and seasonal effects on depth of thaw (right) (Schuur, unpublished data).

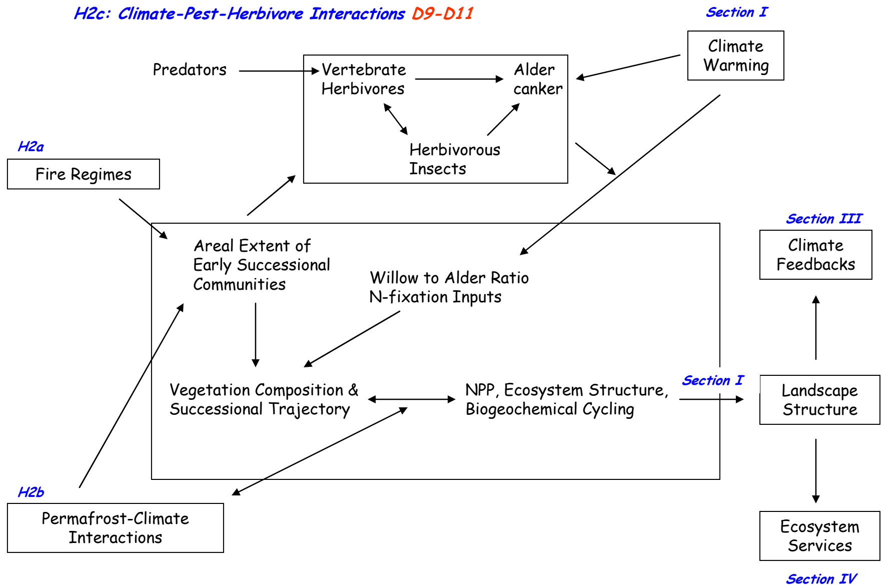


Fig. 32. Conceptual diagram showing how tasks (notations in red) link components with the section on climate-pest-herbivore interactions, and how this section is tied to other proposal components.

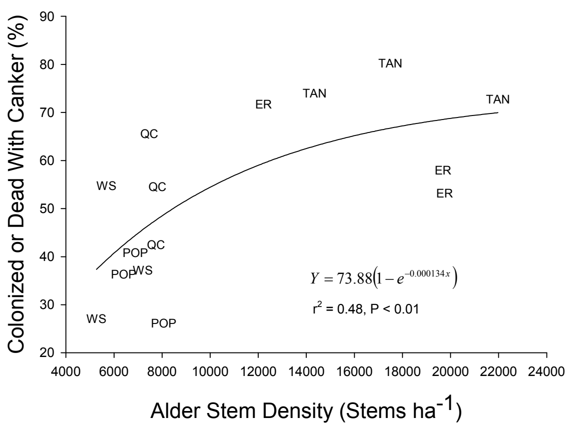


Fig. 33. Relationship between the proportion of *Alnus tenuifolia* ramets either dead or colonized by stem canker at replicate in early-successional stands along the Eagle River (ER), Quartz Creek (QC) and Tanana River (TAN), and mid-successional balsam poplar (POP) and late-successional white spruce (WS) stands along the Tanana River where *A. tenuifolia* dominates the understory shrub canopy (Ruess et al. 2009).

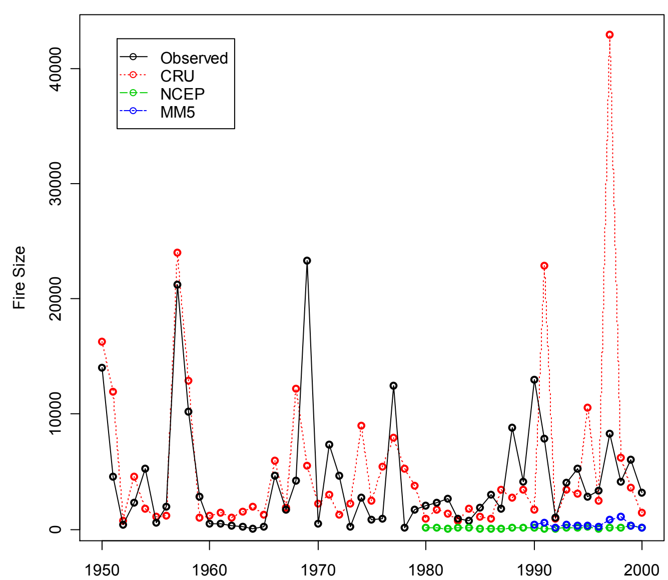


Fig. 34. Time series comparing observed annual area burned to that simulated by ALFRESCO for the three different climate datasets. Simulated results presented as averages across realizations (n = 100): CRU (red), NCEP (green), and MM5 (blue) (Rupp et al. 2007).

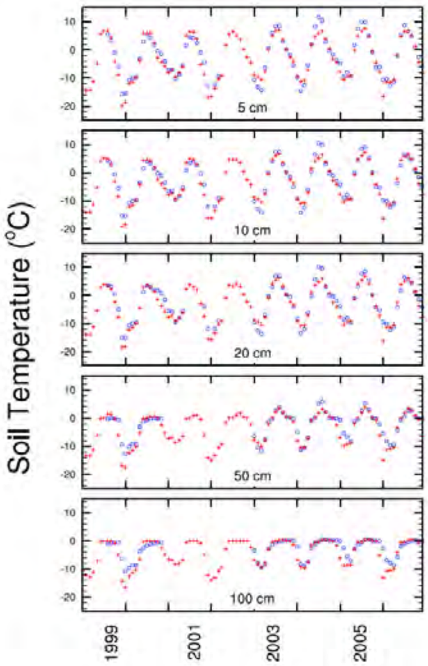


Fig. 35. Comparisons between simulated (red crosses) and measured (blue circles) monthly soil temperatures at different depths of a site from 1999 to 2006, at which fire occurred in 2002 (Yi et al. 2009).

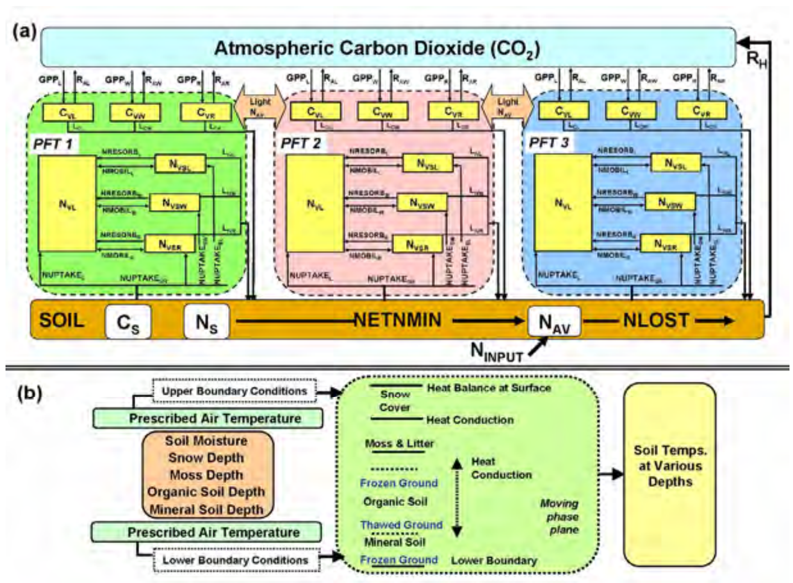


Fig. 36. Fig. 36. Conceptual diagram of the dynamic vegetation model (DVM) of the terrestrial ecosystem model (TEM-DVM) with multiple vegetation pools, including the leaf (L), wood (W) and root (R) pools (a). The model in (a) is coupled to the soil thermal model (STM; b). The example in (a) shows three plant functional types (PFTs), although the number of PFTs may be either more or less in model applications. The arrows with 'light' and 'N' between the PFTs illustrate that competition occurs between the PFTs, as described in the text. R_H = heterotrophic respiration; GPP = gross primary productivity; R_A = autotrophic respiration; C_V = carbon in living vegetation; L_C = litterfall carbon; N_V = N in living vegetation; N_{VS} = structural N in living vegetation; NRESORB = N resorbtion; NMOBIL = mobile N; NUPTAKE = N uptake by the vegetation; C_S = soil carbon; N_S = soil N; NETNMIN = net N mineralization; N_{AV} = available N; NLOST = N lost from the ecosystem (Euskirchen et al. 2009).

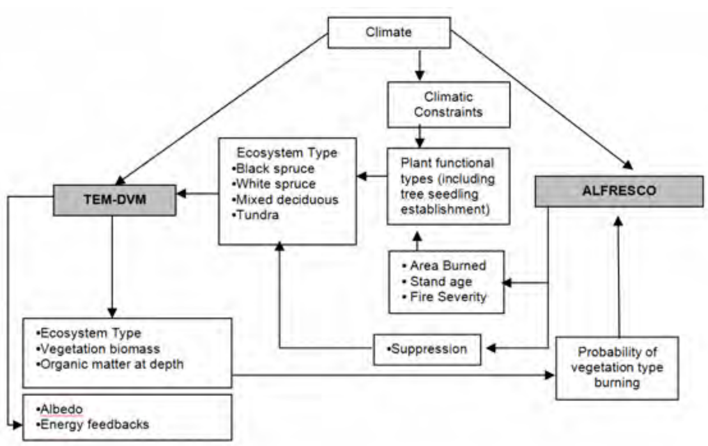


Fig. 37. Diagram of the proposed coupling between the DOS-DVM-TEM-DVM and ALFRESCO models. The climate drivers to the model include air temperature, precipitation, and soil radiation. The vegetation biomass and soil organic matter at depth determine the probability of burning in ALFRESCO. The number and type of plant functional types varies by fire severity, stand age and climatic constraints. The ecosystem types are determined by the type and amount of the PFTs, as well as fire suppression.

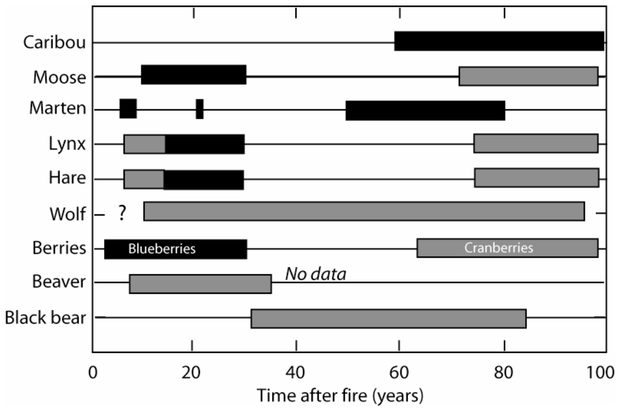


Fig. 38. Shaded areas show approximate periods of optimal habitat conditions after fire events that support higher density or productivity of key boreal forest subsistence species, according to the ecological literature (Kofinas et al. in press). Darker shading represents more important periods.

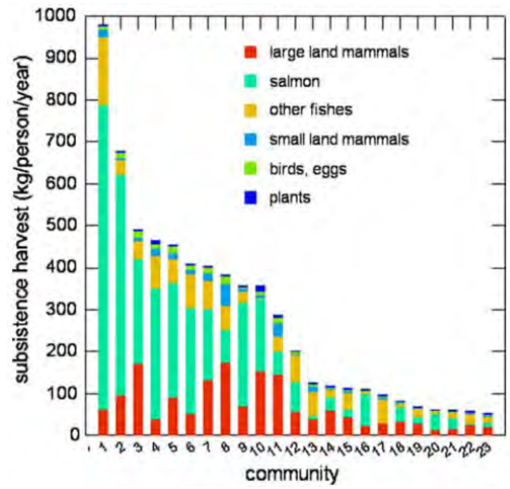


Fig. 39. Composition of annual subsistence harvest for 23 rural communities in interior Alaska (1982–1990 surveys). Communities: 1-Tanana, 2-Hughes, 3-Huslia, 4-Minto, 5-Ft. Yukon, 6-Allakaket/Alatna, 7-Grayling, 8-Anvik, 9-Galena, 10-Nikolai, 11-Holy Cross, 12-Shageluk, 13-Northway, 14-Bettles/Evansville, 15-Tanacross, 16-McKinley Park, 17-Tetlin, 18-McGrath, 19-Tok, 20-Anderson, 21-Healy, 22-Chisana, 23-Dot Lake (Nelson et al. 2008).

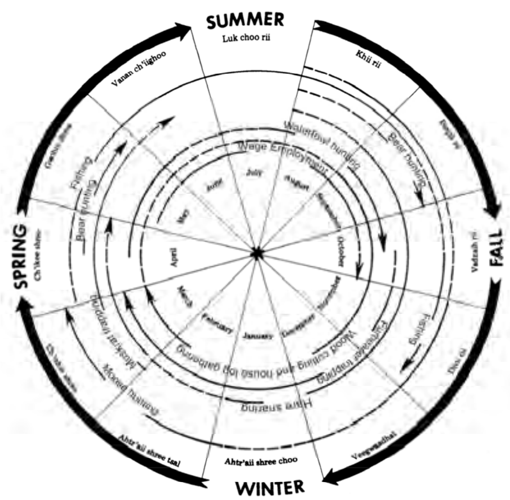


Fig. 40. "Seasonal Round" " of harvesting (i.e. taking moose in the fall, caribou in the fall and winter, ducks in the spring, fish and berries in the summer) (from Caulfield 1983).

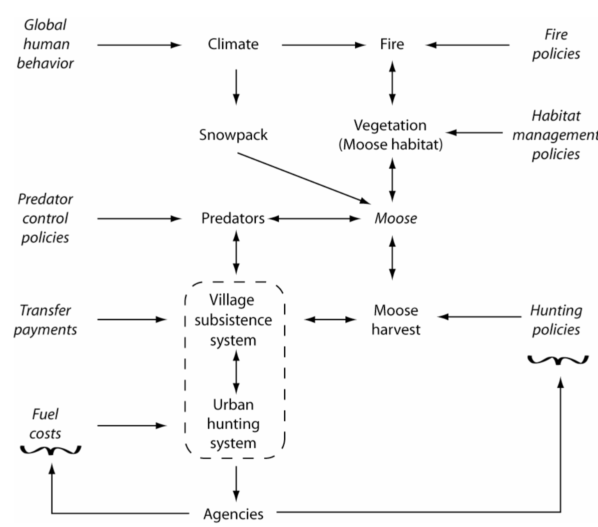


Fig. 41. Influence of climate change, economics, and State and Federal agencies on moose hunting systems in interior Alaska (Kofinas et al. in press).

Table 3. Ongoing (black) and new (red) BNZ LTER research initiatives categorized by ISSE framework components. Task identifiers are in parentheses.

	Direct Effects of Climate	Climate Disturbance Interactions	Climate Feedbacks	Social Ecological Dynamics
Drivers	BNZ climate monitoring Spring snow exclusion (C3) Fire regime (C5) Permafrost modeling (C6)	BNZ climate monitoring Fire-vegetation (D1) Fire-permafrost (D5) Snow fence expt (D7)	BNZ climate monitoring Model coupling (CF1) H_2O & energy model (CF3) CO_2 & CH_4 model (CF4)	BNZ climate monitoring
Biotic Responses	BNZ veg & NPP monitoring Regional site network (C1) Historical NPP (C2) Hare & moose monitor (C4) Insects & path monitor (C7)	BNZ veg & NPP monitoring Species establishment (D2) Succ. trajectories (D3) Snow fence expt (D7) APEX expt (D8) Alder canker (D10) Vert-Invert expt (D11)	BNZ veg & NPP monitoring Model coupling (CF1) Future scenario modeling (CF2)	BNZ veg & NPP monitoring Ecosystem services (SE1) Trajectories of change (SE2)
Landscape Responses	Regional site network (C1) Historical NPP (C2) Hist. pest outbreak (C7)	PSM feedbacks (D4) Watershed hydrology (D6) Permafrost gradient (D7) Pest-vegetation (D9)	Model coupling (CF1) Future scenario modeling (CF2) H_2O & energy model (CF3)	Ecosystem services (SE1) Trajectories of change (SE2)
Societal Impacts	Changing fire regime (C5) Hare & moose monitor (C4)	Biotic effects on fire (D1) Succ. trajectories (D3)	Future scenario modeling (CF2)	Ecosystem services (SE1) Trajectories of change (SE2) Social-ecol modeling (SE3) Institutional analysis (SE4)

Table 4. BNZ involvement in cross-site comparisons (LTER and others) over the history of the LTER.

Project	**Lead PI**	**BNZ PI**
^{15}N Plant-soil tracer experiment	Nadelhoffer	Mack
Anatuvuk River Fire project	Shaver	Mack, Hollingsworth
Climate network	Greenland	Hinzman
Climate variability and ecosystem response	Greenland	Juday
Climate/extreme events (XE)	Goodin	Juday
Controls over moss decomposition	Sveinbjornsson	Sveinbjornsson, Mack
Disturbance dynamics	Turner	Chapin, Yarie
Engaging Arts/Humanities	Swanson	Leigh
Fine root dynamics	Pregitzer	Ruess
High-latitude transects	McGuire	McGuire
Forest Fragmentation and decomposition across a moisture/temperature gradient	Gonzales, Gould	Hollingsworth
Hydrologic processes	Post	Hinzman
LIDET (litter decomposition)	Harmon	Yarie, Valentine
Log decomposition	Harmon	Yarie
LTER Future Scenarios	Foster	Hollingsworth
MAPS and LOCALS (MALS)	Kofinas	Kofinas
NASA-LTER-MODIS		Verbyla
National Soil Carbon Network		Harden
NEON	Schimel	Jones, Mack, Schuur, Yarie
Nutrient fluxes from Experimental Watersheds Network	Johnson	Jones
Paleolimnology of northern lakes	Brubaker	Edwards, Finney
Productivity-diversity relationships	Waide	Juday
Soil amino acid turnover	Ruess	Ruess, Kielland
Stream DOM workshop	Jaffe	Jones
The Disappearing Cryosphere	Ducklow/Williams	Schuur, McGuire
TRENDS	Peters	Chapin, McGuire
USFS-LTER-NADP		Hinzman
USGS Fate of Carbon : Soil chronosequences	Harden	Harden
Yardstick to Gyroscope	Grayson	Kofinas

Section 3: Site Management

Leadership structure

NSF and the USDA Forest Service, through the Pacific Northwest Research Station, jointly fund the BNZ LTER project. The NSF and USFS components of the LTER program are thoroughly integrated into a single program, so we describe the management as it actually functions, rather than distinguishing between the NSF and USFS components. Our leadership team consists of the PI and co-PIs: Ruess, Jones, Hanley, Mack, and McGuire. In 2011, Teresa Hollingsworth will take over Tom Hanley's role as co-PI. Teresa is a Research Scientist at the USFS Boreal Ecology Cooperative Research Unit (http://www.becru.uaf.edu/), and has been co-serving as the USFS representative to the BNZ LTER for the past several years. Scientific decisions in the BNZ LTER are made at several levels:

1. Ruess serves as the PI of the LTER research program and is ultimately responsible to NSF for the overall design and implementation of the research program.

2. In practice, the five-person leadership team makes decisions jointly concerning the design and implementation of the research program. Each of us has responsibility for overseeing specific aspects of the program: Ruess, overall integration (within-site and with network) and site management; Hanley, Forest Service communication; Jones, permafrost/hydrology, Mack, vegetation/fire disturbance; McGuire, data management and modeling.

3. The LTER executive committee (leadership team plus Hollingsworth, Yarie, site manager, data manager, and student representative) meets monthly to provide feedback about major issues associated with program direction (e.g., conceptual framework and general design of this proposal). In practice, these meetings are open to all LTER personnel, and there is broad participation by the LTER community.

4. Two or three individuals are responsible for coordination and integration within each research theme: climate sensitivity (Lloyd and Verbyla), climate-disturbance interactions (Mack, Hollingsworth, Schuur, Ruess), climate feedbacks (Euskirchen, McGuire, Rupp), human dimensions (Kofinas, Kielland, Rupp).

5. There are 1-2 leaders plus a planning team responsible for designing and implementing each research task (Table 5) and for making sure that this research addresses the hypotheses and questions of the research themes and the overall project goals.

6. Each investigator is allocated a budget and is responsible for designing and implementing her/his portion of the research program (see Budget Justification).

Program integration and communication

We will continue to meet monthly to address practical issues and to plan and coordinate our within-site synthesis activities and annually at our research symposium to conduct synthesis of our major themes (climate sensitivity, climate-disturbance interactions, climate feedbacks, human dimensions). A final level of communication and integration is often facilitated by the need to coordinate transportation for travel to field sites.

Budgeting and accountability

Each PI is responsible for her/his own budget and implementation of research. Every two years each investigator must submit a progress report that includes major findings, publications, datasets that are on line or being prepared, and a mini-proposal that describes research plans for the next two years. These reports and mini-proposals serve as a basis for evaluation and budget reallocation by the leadership team. If necessary, more frequent budget reallocations will occur at the time of the annual progress report to NSF, as we have done in the past. Project PIs also obtain separate project funding to complement their BNZ LTER-funded research (Additional BNZ-related research (2005-2010) = $38.71 million, which translates to $7.9 per NSF-LTER $; see Budget Justification, Table 8). In addition to budgets for each research project, we maintain separate budgets for core research, data management, and general project costs. Core research includes monitoring of climate, hydrology, vegetation, and other essential long-term site measurements. General project costs include national travel, and some infrastructure costs.

Site security and site management

The BNZ research program has two intensive research areas: 1) The Bonanza Creek Experimental Forest (BCEF) is located within the Tanana Valley State Forest and is leased to the USFS (renewable in 2018). 2) The Caribou-Poker Creeks Research Watersheds (CPCRW) includes lands under the jurisdiction of the University of Alaska and the Alaska Department of Natural Resources. The LTER manages BCEF and CPCRW for the purpose of conducting research. We have close working relationship with Alaska Department of Natural Resources, Division of Forestry and Division of Lands, Mining and Water to protect the long term availability of these areas for research. The BNZ site manager (Jamie Hollingsworth) is responsible for managing LTER research in the two research sites, including permitting, transportation, and the planning and implementation of the core research program. Significant improvements in site management in the last funding cycle include expanding our sensor network with radio communications for our 10 plus microclimate stations, improved coordination of field work, improved boat communication and safety, and assessment of statistical power and required sample sizes for long-term vegetation measurements. These efforts have substantially improved the quality, continuity, efficiency, and safety of data collection, releasing time to undertake new activities. As mentioned above, we plan on expanding our monitoring program to include a new regional network of black spruce sites that more closely match our evolving focus on resiliency and mechanisms of landscape change. These sites will be positioned within 3 interior Alaska ecoregions on land owned by the State of Alaska where we are currently working and necessary research permits are being obtained.

The CPCRW is the candidate core site for the taiga domain of NEON, which will provide the infrastructure to measure larger scale measurement of CO_2, CH_4 and water vapor fluxes, and energy exchanges. Additionally, relocatable towers for the taiga domain will be installed in the burned portion of the CPCRW and at our Eight Mile Lake watershed site to examine the effects of wildfire and permafrost thaw on ecosystem C and energy exchanges. CPCRW will also be host to a NEON aquatic array and a STREON site, which will provide the infrastructure to examine stream hydrology, and DOC and nutrient fluxes at a higher temporal resolution than is currently possible, and will allow expansion of our watershed solute export studies to higher-order streams.

Engagement of new investigators, non-LTER scientists, and the Fairbanks community

We added 6 new investigators to our research team in the last 4 years and 3 more in the current proposal, and have adjusted individual budgets to meet the needs of our focus on mechanisms of resilience, climate feedbacks and human dimensions. New investigators include Eugenie Euskirchen (modeling) and Diane Wagner (insect-plant interactions). Mary Beth Leigh (IAB faculty member and professional dancer) recently joined the BNZ LTER as our liaison to the Fairbanks arts community, and has organized several community events bringing together ecologists and local artists (http://www.lter.uaf.edu/outreach/bnz_Collaboration.cfm). Lisa Crone, a research economist with the USFS in Sitka will be joining BECRU in 2010 and expects to focus her research on BNZ LTER activities, most likely on the economics of rural subsistence communities. We have been modestly successful in increasing diversity at our site, going from one woman and no minorities 10 years ago to 11 women (42%) and one minority among the PIs in our current proposal. Of the 61 BNZ LTER graduate students who have completed their degrees since 2004, 52% were females and 5% were minorities. We currently have 48 BNZ LTER graduate students, of which 58% are females and 10% are minorities. Our major effort to enhance diversity is through recruitment of minority graduate students, particularly Alaska Natives. Minority recruitment has been a strong emphasis of the IGERT program in Resilience and Adaptation (see Outreach), and many of these students become involved in BNZ LTER research. A key way in which we engage non-LTER investigators in our LTER research is through our affiliate LTER investigator program (Table 6). The BNZ LTER affiliates are encouraged to participate in our annual symposium, have the same access to LTER data, field sites, and facilities as do LTER Senior Researchers, and are encouraged to archive their data in the LTER database. Terry Chapin has moved into the role of affiliate LTER investigator, and we anticipate close interactions with him and his research program up until (and likely after) his retirement. We attempt to provide transportation costs to the LTER symposium and assist with field logistics whenever possible. Many affiliates have written proposals with LTER investigators as a result of this collaboration.

Table 5. Planning team responsibilities for research tasks: C = Direct Effects of Climate; D = Disturbance-Climate Interactions; CF = Climate Feedbacks; SE = Social-Ecological Dynamics.

	Primary Responsibility	Secondary Responsibility
Euskirchen	CF3	CF1,CF2,CF4
Harden	D8,CF4	D6,D7
Hollingsworth	C1,D2	C5,D1,D3
Johnstone	D3,D4	C1,C5,D1, D2
Jones	D6	D7
Juday	C7,D9	
Kasischke	C5,D1	
Kielland	C4,D11	D2,D10,SE1,SE2,SE5
Kofinas	SE1-5	
Leigh	Community Outreach	
Lloyd	C2,C7	C1
Mack	C1,D3,D4	C5,D1
McGuire	CF1,CF2,CF4	C6,D5,D8
Mulder	D2	
Romanovsky	C6,D5	
Ruess	C7,D9,D10	C1,D2,D11,SE5
Rupp	CF1,CF2	C5,D1,SE1-3
Schuur	D7	C6,D4,D6
Sparrow	SYLTER	
Taylor	D2	D10
Turetsky	D8	CF4
Valentine		C3
Verbyla	C2	
Wagner	C7,D11	D9
Yarie	C3	C1

Table 6. BNZ LTER affiliate scientists and their principal research areas and primary contacts with LTER PIs. BNZ affiliate scientists are encouraged to participate fully in LTER activities (attend symposia, participate in monthly meetings, use and contribute to LTER database) and to receive logistic support to the extent possible, but they do not receive LTER funds to support their research.

Research Area	Affiliate scientist	LTER collaboration
Climate Effects		
Climate transect	Berg	McGuire
Fire behavior	Sandberg	Kasischke, Rupp
Permafrost dynamics	Fukuda	Schuur, Romanovsky
Snowshoe hare population dynamics	DiFolco, Forbey	Kielland
Stand-age reconstructions	Mann	Lloyd, Rupp
Tree ring studies	Fastie, Barber	Lloyd, Juday
Disturbance Climate Interactions		
Herbivory	Person	Kielland, Ruess
Microbial ecology	McFarland,, Waldrop	Kielland, Mack, Taylor
Plant pathogens	Roy, Stanosz, Worrall	Mulder, Ruess
Plant Insects	Kruse, Werner	Wagner, Juday, Ruess
Plant species effects	Bret-Harte, Chapin	Mack, Hollingsworth
Climate Feedbacks		
Remote sensing of forest function	Goetz	Mack, Kasischke, Lloyd
Remote sensing of energy balance	Randerson	Mack
Social-Ecological Dynamics		
Food sharing networks	Gerlach	Kofinas, Kielland
Social-ecological resilience modeling	Martin, Vlacic, Gerlach, Chapin	Kofinas, Rupp, McGuire, Crone, Kielland,
Village ecosystem services	Chapin, BurnSilver	Kofinas, Crone, Rupp
Outreach and Agency Interactions		
Alaska Dept. of Fish & Game	Kellie, Brainerd	Kielland
Alaska Fire Service	Miller	Rupp, Kasischke
Arts/Humanities	Swanson	Leigh
K-12 Education	Kopplin, Stephens	Sparrow
National Park Service	DiFolco	Kielland
Rural Community Partnerships	Gerlach, BurnSilver, Chapin	Kofinas
State Division of Forestry	Maisch	Juday
US Fish & Wildlife Service	Bertram	Kielland, Ruess, Hanley
US Geological Survey	McCree, Waldrop	Harden, McGuire
USFS State and Private Forestry	Kruse, Winton	Wagner, Ruess

Section 4: Information Management

Goals and objectives:

Information management plays an integral role in the support of site operations and contributes to broader LTER network activities. The primary goals of data and information management at the BNZ LTER are to ensure the long-term archival of the program's datasets. We employ current technologies and data management techniques in order to provide a system that engenders trust, collaboration and efficient information exchange. Of primary concern are metadata, quality control, accessibility, timeliness of data availability, and the security of datasets. Additionally, the data manager explores the possible use of new technologies in data management.

Background:

We hired our current data manager, Jason Downing, in 2007. Jason has worked with the leadership team and BNZ support staff to develop and improve our long-term procedures for information management. Our database system has been designed to ensure continuity of BNZ data management structure and implementation, regardless of potential future personnel changes. Substantial effort has been put into documenting information management operations and products.

The current data management system:

At BNZ the primary role of the data manager is to provide the tools and system architecture to accommodate secure long-term archival of LTER datasets. In addition, the data manager provides advice to investigators in the areas of data management, software selection and use, and keeps abreast of new opportunities from innovative software and hardware developments or new trends in data management technology. The data manager also offers advice and expertise in data collection, storage, and archival issues where needed, particularly as new studies are designed. The BNZ data manager is also the IM representative at all LTER network activities. These activities range from annual IM meetings to participation in network efforts to design future network tools.

The keystone component of our data management system is an extensive mySQL relational database containing all pertinent site, personnel, publication, and dataset information. It serves as the ultimate repository for our core climate monitoring data sets and several of our other key data sets on vegetation, production, and hydrology.

While we still rely on the use of text files as the primary means of data dissemination, we have added a new secondary database that takes in all manual and telemetry accessible climate station data and provides an instant visual. This new database functions to provide real-time graphical representations of our data and tools to perform quality assurance and control procedures on the data before they are migrated into the primary database. The climate station data are available to users through a web interface (http://www.lter.uaf.edu/bnz_vdv.cfm). This system not only allows for up-to-the-hour data graphs and access to the data, it facilitates quality assurance and control, and database transfer tasks.

Datasets in the BNZ LTER database are available to other scientists in as timely a manner as possible at www.lter.uaf.edu/data_b.cfm, where there are detailed data, EML metadata, and publication lists. (A complete list of online databases can be found in Supplementary Documents). Full pdfs of publications are available through the publication web page to promote distribution of BNZ-LTER published results. Core climate data are uploaded to the website monthly for public access. All other datasets are updated or added as soon as annual fieldwork ends and the data are entered and checked for quality. In general, datasets are made publicly available as soon as they are archived.

System integrity is of paramount importance for a program dedicated to long term archival of information. Our strategy includes routine backup of essential data and informed use of software and hardware defenses to prevent unauthorized intrusion in case the system is compromised.

Data reside on each investigator's computer until archived on the main server. It is the responsibility of the investigator to ensure that their data are safe and backed-up while in their possession. Each site database is backed up daily to the data manager's personal workstation, which is additionally backed up to a data tape weekly. At the end of each month, these database backups are consolidated into two backups and burned to CD for storage off site. The servers are backed up off-site to the University of Alaska Fairbanks Arctic Region Supercomputing Center. The servers are currently located in a university-managed computer center which provides a locked, secure, and environmentally controlled area. The servers are protected from unauthorized intrusion by hardware and software firewalls, limited remote accessibility, a minimum number of user accounts, and password requirements.

There are a number of newly emerging data types such as molecular data, social science data, and digital image archives that are presenting additional challenges for information management. Our staff is developing new procedures to accommodate the archival and dissemination of these data to the greater community. Our molecular data are hosted on an internal database facilitated by the university bioinformatics group where they are processed for quality. Once specific sequence data are finalized, they are submitted to GenBank and will be mirrored in the BNZ database and become accessible for discovery and utilization. Social science data such as interviews and questionnaires are also becoming increasingly significant resources for our research. This type of information is generally represented as transcripts, meeting reports, interviews, and maps and will require the additional development of our metadata system. It will also require us to address the security and protection of some potentially sensitive private data. Finally, as digital imaging technology advances, we are generating an exponentially-growing volume of digital files. We offer a secure archive location for investigators to backup image archives and plan to develop a new image search engine on our website.

The worldwide web provides an efficient means of serving information about our program. The primary database also serves as a back end for our public web pages to provide the most current content and metadata information as possible to users. Server logs indicate that our site receives numerous visitors each month and our data are regularly downloaded. We have one of the most liberal dataset access systems in the LTER network, and we are currently working with the network office to begin using their data access server to track downloads of our data. We hope to be operational within the next year.

Participation of scientists in data archival and data manager activities:

The data manager interacts with investigators at several levels. First the data manager attends all monthly BNZ staff meetings and monthly BNZ general group meetings. Graduate students are encouraged to consult with the data manager prior to their first field season and throughout their project as needed. We have recently increased data manager involvement with key site investigators by increasing regular meetings and adding field visits for various projects to enhance the data manager's understanding of individual researchers and their specific data needs. The data manger is encouraged to suggest new ideas and changes to procedures for data collection, data archival, and research products. Training on metadata standards, data care and data submission has been provided and individual consulting is available. There is continuous interaction and changing of webpage layouts and functions in response to needs or concerns of investigators.

Our data archival policy is that investigators must submit project data within two years of collection. Compliance with our data archival policy is mandatory and supported by our leadership team. Data archival has become an important aspect of our internal review and budget reallocation process. Investigators who fail to submit their data for online archival and use will not receive continued LTER funding. Compliance is assessed annually by the data manager and one of the members of the leadership team (McGuire), who together meet with each investigator to discuss current activities, the status of their data submissions, and to communicate the need for compliance with non-compliant investigators. Our recent emphasis on the necessity for dataset submittal has substantially increased the rate of dataset submittal. An increased effort to reach out to graduate students and faculty is reaping an improved quality and volume of data submissions. Greater involvement in data archival is also evolving as scientists see data archival as beneficial to them. For example, the data management staff has been able to enhance archival of data by providing useful tools that help organize and enhance the quality of data for the scientists. We are also linking publications with data sets on the web site so data that give rise to a publication can easily be identified, accessed, and properly acknowledged.

Dataset quality control is the responsibility of the submitting principal investigator. Scientists rely on various quality control methods including plotting, visual inspection, and programmatic range checking. The data manager assists in quality control efforts where technical solutions are requested.

Local and Network-level activities:

The BNZ LTER shares a computer network with the broader University of Alaska Fairbanks and receives much of its computing support through participation and agreements with the Arctic Region Supercomputer Center and the Alaska Idea Network for Biomedical Research Excellence. We provide services to the community as well with file hosting, large format map scanning, and data consultations. BNZ LTER staff involvement in the larger computing community issues provides opportunities to leverage BNZ LTER investments with additional computing resources and staff at the university and network levels.

The BNZ LTER data manager is active in LTER NIS programs and network working groups. BNZ LTER contributes to ClimDB, HydroDB, SiteDB, Personnel database, Bibliography database, and the LTER Trends module. Jason Downing, our current data manager, is active in IM working groups dealing with keywords and EML quality. He has also served as editor for the two most recent issues of DataBits and has additionally contributed articles to this publication.

We now have EML documents harvested for each of our datasets by the LNO Metacat Harvester. These documents are all at the minimum level necessary for discovery (Level 2) but the majority is at a higher level. Work continues at our site to increase the richness and quality of all our EML documents in hopes of providing Level5 EML for every data set.

Anticipated system enhancements:

We pride ourselves on our data management system at Bonanza Creek LTER and are continually looking for ways to improve the system. This section outlines four future services.

Web design upgrades: By taking into account the best practices that the IM community has outlined for LTER websites, we are working to bring our website into a more standardized look to achieve greater uniformity among the LTER sites. We are also developing modifications to the site searching capabilities and access to archive documentation that will improve support of synthesis activities and information outreach.

Database/Server upgrade: We have recently transitioned to a virtualized server system where our database and web application servers are now residing on a single computer server. This server has been relocated to a university operated computer machine room to improve system security and provide a controlled environmental climate.

Ecological Metadata Language and Data Synthesis: We intend to continue our goal of enriching all of our current EML documents to Level 5 (access/integration). This work will require investigating legacy data to locate missing information and solicit researchers for additional documentation. The data manager is also standardizing our most frequently requested data so they can be readily used in synthesis activities.

Expansion of internet map services and GIS capability: The field of GIS and mapping services is continually changing and we are working to keep abreast of current technologies. We have recently released a new version of ArcGIS Server that utilizes an Oracle Database as the back end for spatial data. The web mapping application allows users to see graphic representations of research study sites, administrative boundaries and ecological characteristics of interior Alaska as well as highlights of some of our most recent spatial data acquisitions. Our site manager, Jamie Hollingsworth, has an extensive GIS background and takes the lead role on the development and management of the GIS modules. Jamie is also a leader in the network group developing network wide standards and tools to display and disseminate spatial data.

Section 5: Education and Outreach

K-12 Education: The Schoolyard LTER (SLTER) program has been one of the most successful components of BNZ outreach, involving numerous BNZ scientists and graduate students. We have teamed with three similar science education programs, Global Learning and Observations to Benefit the Environment or GLOBE (NASA and NSF), Global Change Education Using Western Science and Native Observations (NSF), and an international project called Seasons and Biomes (NSF) to train science teachers from 50 Alaskan towns and villages in engaging students in long-term environmental research. LTER funding enabled 6 elementary and high school teachers to be added to the program. These schools now have their own long-term ecological research projects and have developed web sites. We developed a phenology unit involving K-12 students in ground validation of remotely sensed data, a first such opportunity for rural Alaskan students. This module has been incorporated into the GLOBE Teacher's Guide and is used internationally (189 schools in 20 countries have reported phenology data archived at www.globe.gov). In 2008, three rural Alaskan students with their Native elder mentors were funded by GLOBE to present their boreal forest regrowth study (initiated after a 2005 fire) and their Athabaskan perspective on climate change at the International GLOBE Learning Expedition in South Africa (students from 24 countries participated) (Fig. 42). They were also awarded the Alaska Spirit of Youth Award recognizing outstanding work of young Alaskans in their community. In the coming phase of LTER research we will continue efforts to integrate traditional ecological knowledge into the science curriculum in rural schools as part of our involvement in the joint SYLTER-GLOBE program.

In 2006, LTER helped to develop a High School Summer Research Internship Program (HSSRIP), whereby high school students from rural Alaska come to Fairbanks for six weeks to participate in research projects with LTER scientists. Students give presentations on their research projects at the end of the session. The work of two students was recently featured in a book on high-latitude climate change (ref).

A K-6 curriculum on Alaskan invasive plants was developed by Katie Villano while she was an LTER graduate student, and several BNZ scientists co-led field trips for students in the program. The curriculum is now being used in Fairbanks schools and other schools throughout Alaska (ref).

In 2009, an interdisciplinary art/science course was developed by Mary Beth Leigh (BNZ LTER scientist) for middle school students at Effie Kokrine Charter School in Fairbanks, a school with a 90% enrollment of Alaska Native students. The course, *Climate Change and Creative Expression*, integrated creative writing and dance with climate change science and Alaska Native knowledge, and was offered for early college credit to 18 self-selected students (Fig. 43). The scientific portion of the curriculum included guest lectures by LTER PIs and a winter field trip and visits to campus research labs, where students had hands-on experiences with tree coring and dating and permafrost depth monitoring. The course culminated in a book of student poems and a public performance including poetry readings, theater, dance and music created and performed by the students that communicated their knowledge, thoughts and feelings about climate change in Alaska. BNZ scientists regularly work with local K-12 teachers, serve as judges in science fairs, and mentor high school students on science-fair projects, leading to several top honors in statewide, national, and in the case of one student, an international competition. One SLTER teacher received the Presidential Award for Excellence in Math and Science Teaching for elementary teachers. LTER graduate students and the SLTER PI have also been active in the GK-12 Teaching Alaskans, Sharing Knowledge program at UAF in which graduate students share their science expertise in K-12 classrooms while gaining experience in communicating their science and working with diverse audiences such as K-12 students and teachers. BNZ SLTER continues to participate in national LTER Education and Outreach committee and activities.

University Education: UAF faculty regularly use BNZ LTER research sites for field trips and laboratory exercises because of its proximity to campus. Undergraduates also participate in summer research as REU students or RAs. An REU symposium at the end of each summer provides opportunities for students to present their results formally and receive feedback from faculty and other students. BNZ LTER conducted field classes for approximately 30 students in the Ecological Society of America Strategies for Ecology Education, Development, and Sustainability (SEEDS) program and in the United Negro College Fund Student Excellence Equals Degree (SEEDS) program in June and

August, 2008, respectively. At the graduate level, the BNZ LTER has been an important venue for training graduate students in ecology. There are currently 48 BNZ LTER graduate students (61 graduated since 2004) conducting research through the BNZ LTER program from biological, geophysical and social sciences. Recent additions to our graduate community are interdisciplinary students in Resilience and Adaptation, an NSF-sponsored IGERT graduate program linking ecological, economic, and cultural aspects of sustainability and resilience. Graduate students participate in the LTER program by conducting their own research, collecting long-term data, organizing research discussions and seminar series, and leading cross-site synthesis activities. The BNZ LTER staff and investigators provide research support, logistics, training and mentoring for incoming graduate students. We have expanded this support with the addition of an annual graduate orientation and site-wide research symposium to better connect students with investigators to promote collaboration. Graduate students collaborate in all aspects of BNZ LTER from proposal development to research. We will continue to support current within-site and cross-site graduate collaborations and encourage the incorporation of synthesis into new graduate research.

Outreach to Communities, Agencies, and the General Public: BNZ has established successful interactions between artists and scientists resulting in performances for the general public on the theme of climate change. The LTER has hosted two field-based workshops and several informal meetings bringing together writers, musicians, dancers, visual artists and BNZ scientists. The first field trip focused on climate change and wildfire in Alaska, and culminated in a public performance "*In a Time of Change*" in 2008 (Fig. 44). The performance played to a filled theater (>350 attendees) and featured poetry and theater by renowned Alaskan writers, including two former Poets Laureate of Alaska, plus lectures and artistic work by LTER PIs, original music and a dance piece based on BNZ LTER data (http://www.lter.uaf.edu/outreach/bnz_Collaboration.cfm). Another series of field workshops, followed by a new stage performance, gallery exhibition and mini tour of Alaska are scheduled for 2010. A cross-site collective meeting is planned with three other LTER sites involved in the arts, to envision possible site-based futures under different land-use and/or climatic scenarios. BNZ scientists will continue leading activities to reach out to artists, performers, writers and the public.

We collaborate with the Alaska Native Science Commission (ANSC) in their program to address the environmental and ecological concerns of Native Alaskans. We participate annually in a community meeting that ANSC organizes, with each year focusing on a different region of Alaska. We provide information on the long-term ecological changes that we observe and we listen to and discuss with Native leaders their concerns about environmental changes that affect their subsistence and cultural activities.

We work closely with numerous state and federal agencies and Native organizations through joint research programs, discussions of management issues, jointly organized seminars, training programs for agency staff, and participation on Citizens' Advisory Committee for the Tanana Valley State Forest. The active role that these managers have played in our LTER synthesis is indicative of the close working relationship that we have developed with resource managers in Alaska. We are also involved in the Interior Issues Climate Change Task Force, for example on the Climate Change Adaptation Advisory Group and Climate Change Education Group. Due to the continued national and international concern about climate warming, we are regularly interviewed by radio and television stations (including foreign media), newspapers, journals, and film crews. We have also provided testimony on climate change to U.S. House of Representatives, Committee on Science and Technology and to the Alaska Governor's cabinet.

Ties to other Long-Term Research Programs: Our closest ties within the LTER network are with the ARC LTER site at Toolik Lake. A number of BNZ researchers work extensively at Toolik and maintain collaborations with ARC LTER researchers. We also maintain strong ties with other forested LTER sites and are strengthening ties with sites engaged in social-ecological research. We work closely with the National Park Service with their Long-Term Monitoring program in Alaska and participate in one another's research symposia. We also work closely with U.S. Fish and Wildlife Service research programs in the Arctic Wildlife Refuge, the Yukon Flats Refuge and the Kenai National Wildlife Refuge, with ecological monitoring programs on military bases in interior Alaska, and with researchers engaged in ecological consulting.

Fig. 42. Students from Innoko River School, Alaska at the 2008 GLOBE Learning Expedition held in Capetown, South Africa

Fig. 43. Middle school student in *Climate Change and Creative Expression* class age trees on a field trip to BNZ.

Fig. 44. Scenes from *In a Time of Change: A Performance by Writers, Artists and Scientists*, which focused on climate change and wildfire in Alaska and played to over 350 members of the public (2008). Top: Dancers perform the piece “Casting Shadows” based on 25 years of BNZ LTER post-fire plant succession data. Bottom: Children performing the song “What’s a Shrew to You”, which was later published as a children’s storybook with CD.

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200. Taylor DL, Herriott IC, Long J, & O'Neill K (2007) TOPO TA is A-OK: a test of phylogenetic bias in fungal environmental clone library construction. *Environmental Microbiology* 9(5):1329-1334.
201. Taylor DL*, et al.* (in press) Structure and resilience of fungal communities in Alaskan boreal forest soils. *Canadian Journal of Forest Research*.
202. Tinner W*, et al.* (2008) A 700-year paleoecological record of boreal ecosystem responses to climatic variation from Alaska. *Ecology* 89(3):729-743.
203. Trainor SF*, et al.* (2009) Vulnerability and adaptation to climate-related fire impacts in rural and urban interior Alaska. *Polar Research* 28(1):100-118.
204. Turetsky MR, Mack MC, Hollingsworth TN, & Harden JW (in press) Patterns of moss productivity, decomposition, and suggession: implications for the resilience of Alaskan ecosystesm. *Canadian Journal of Forest Research*.
205. Turetsky MR*, et al.* (2008) Short-term response of methane fluxes and methanogen activity to water table and soil warming manipulations in an Alaskan peatland. *Journal of Geophysical Research-Biogeosciences* 113:Article Number: G00A10.
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209. Van Cleve K, Chapin FS, III, Flanagan PW, Viereck LA, & Dyrness CT eds (1986) *Forest Ecosystems in the Alaskan Taiga: A Synthesis of Structure and Function* (Springer-Verlag, New York).
210. Verbyla D (2008) The greening and browning of Alaska based on 1982-2003 satellite data. *Global Ecology and Biogeography* 17:547-555.
211. Viereck LA, Dyrness CT, Van Cleve K, & Foote MJ (1983) Vegetation, soils, and forest productivity in selected forest types in interior Alaska. *Canadian Journal of Forest Research* 13:703-720.
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213. Wagner D, DeFoliart L, Doak P, & Schneiderheinze J (2008) Impact of epidermal leaf mining by the aspen leaf miner (Phyllocnistis populiella) on the growth, physiology, and leaf longevity of quaking aspen. *Oecologia* 157(2):259-267.

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216. Walsh JE, Chapman WL, Romanovsky VE, Christensen JH, & Stendel M (2008) Global climate model performance over Alaska and Greenland. *Journal of Climate* 21:6156-6174.
217. Walter KM, Edwards ME, Grosse G, Zimov SA, & Chapin FS (2007) Thermokarst lakes as a source of atmospheric CH4 during the last deglaciation. *Science* 318(5850):633-636.
218. Walter KM, Smith LC, & Chapin FS (2007) Methane bubbling from northern lakes: present and future contributions to the global methane budget. *Philosophical Transactions of the Royal Society a-Mathematical Physical and Engineering Sciences* 365(1856):1657-1676.
219. Walter MK, Zimov SA, Chanton JP, Verbyla D, & Chapin FS, III (2006) Methane bubbling from Siberian thaw lakes as a positive feedback to climate warming. *Nature* 443:71-75.
220. Welp LR, Randerson JT, & Liu HP (2007) The sensitivity of carbon fluxes to spring warming and summer drought depends on plant functional type in boreal forest ecosystems. *Agricultural and Forest Meteorology* 147(3-4):172-185.
221. Werdin-Pfisterer NR, Kielland K, & Boone RD (2009) Soil amino acid composition across a boreal forest successional sequence. *Soil biology & biochemistry* 41(6):1210-1220.
222. Werner RA, Raffa KF, & Illman BL (2006) Dynamics of phytophagous insects and their pathogens in Alaskan boreal forests. *Alaska's Changing Boreal Forest*, eds Chapin FS, III, Oswood MW, Van Cleve K, Viereck LA, & Verbyla DL (Oxford University Press, New York), pp 133-146.
223. Wickland KP & Neff JC (2008) Decomposition of soil organic matter from boreal black spruce forest: environmental and chemical controls. *Biogeochemistry* 87(1):29-47.
224. Wickland KP, Neff JC, & Aiken GR (2007) Dissolved organic carbon in Alaskan boreal forest: Sources, chemical characteristics, and biodegradability. *Ecosystems* 10(8):1323-1340.
225. Wickland KP, Striegl RG, Neff JC, & Sachs T (2006) Effects of permafrost melting on CO2 and CH4 exchange of a poorly drained black spruce lowland. *Journal of Geophysical Research-Biogeosciences* 111(G2).
226. Wilmking M, Harden J, & Tape K (2006) Effect of tree line advance on carbon storage in NW Alaska. *Journal of Geophysical Research-Biogeosciences* 111(G2).
227. Wilmking M, Juday GP, Barber V, & Zald H (2004) Recent climate warming forces contrasting growth responses of white spruce at treeline in Alaska through temperature thresholds. *Global Change Biology* 10:1-13.
228. Wirth C, Lichstein JW, Dushoff J, Chen A, & Chapin FS (2008) White spruce meets black spruce: Dispersal, postfire establishment, and growth in a warming climate. *Ecological Monographs* 78(4):489-505.

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230. Yarie J (2008) Effects of moisture limitation on tree growth in upland and floodplain forest ecosystems in interior Alaska. *Forest ecology and management* 256(5):1055-1063.
231. Yarie J & Van Cleve K (in press) Resilience dynamics tied to long-term monitoring of climate and nutritional effects on tree growth of interior Alaska. *Canadian Journal of Forest Research*.
232. Yarie J & Van Cleve K (submitted) Resilience dynamics tied to long-term monitoring of climate and nutritional effects on tree growth of interior Alaska. *Canadian Journal of Forest Research*.
233. Yi S, Manies KL, Harden J, & McGuire AD (2009) Characteristics of organic soil in black spruce forests: Implications for the application of land surface and ecosystem models in cold regions. *Geophysical Research Letters* 36:L05501.
234. Yi S*, et al.* (2009) Interactions between soil thermal and hydrological dynamics in the response of Alaska ecosystems to fire disturbance. *Journal of Geophysical Research-Biogeosciences* 114:G02015.
235. Yi S*, et al.* (In review) A dynamic organic soil biogeochemical model for analyzing carbon responses of black spruce forests in Interior Alaska. *Journal of Geophysical Research-Biogeosciences*.
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237. Young BD, Wagner D, Doak P, & Clausen TP (In review) Induction of phenolic glycosides by aspen (*Populus tremuloides*) in response to epidermal leaf mining by *Phyllocnistis populiella*. *Journal of Chemical Ecology*.
238. Young BD, Wagner D, Doak P, & Clausen TP (In review) Within-plant distribution of phenolic clycosides and extrafloral nectaries in trembling aspen, *Populus tremuloides*. *American Journal of Botany*.
239. Zhuang Q*, et al.* (2004) Methane fluxes between terrestrial ecosystems and the atmosphere at northern high latitudes during the past century: A retrospective analysis with a process-based biogeochemistry model. *Global Biogeochemical Cycles* 18:GB3010.
240. Zhuang Q*, et al.* (2007) Net emissions of CH_4 and CO_2 in Alaska: Implications for the region’s greenhouse gas budget. *Ecological Applications* 17:203-212.
241. Zhuang Q*, et al.* (2006) CO_2 and CH_4 exchanges between land ecosystems and the atmosphere in northern high latitudes over the 21st century. *Geophysical Research Letters* 33:L17403, doi:17410.11029/12006GL026972.
242. Zimov SA, Schuur EAG, & Chapin FS, III (2006) Permafrost and the global carbon budget. *Science* 312:1612-1613.

CURRICULUM VITA

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Education

B.S.	1974	University of California Irvine, Biological Sciences
Ph.D.	1980	University of North Dakota, Biology

Professional Experience

Professor of Biology, University of Alaska, 2001-present
Assistant, Associate Professor of Biology, University of Alaska; 1989, 1994
Research Assistant Professor, Syracuse University, 1987-1989
National Science Foundation Postdoctoral Fellow, 1985-1987
Post-doctoral Research Assistant, Syracuse University, 1980-1984

5 Recent Publications

Anderson, M.D., R.W. Ruess, D.D. Myrold, and D. L. Taylor. 2009. Host species and habitat affect nodulation by specific *Frankia* genotypes in two species of *Alnus* in interior Alaska. Oecologia 160: 619-630.

Chapin, F.S., III., J.W. McFarland, A.D. McGuire, E.S. Euskirchen, R.W. Ruess, and K. Kielland. 2009. The changing global carbon cycle: linking local plant-soil processes to global consequences. Journal of Ecology 97: 840-850.

McFarland, J.W., R.W. Ruess, K. Kielland, K.S. Pregitzer, R. Hendrick and M. Allen. Cross-ecosystem comparisons of *in situ* plant uptake of amino acid-N and NH_4^+. Ecosystems (*in press*).

Mitchell, J.S., and R.W. Ruess. N_2 fixing alder (*Alnus viridis spp. fruticosa*) effects on soil properties across a secondary successional chronosequence in interior Alaska. 2009. Biogeochemistry 95: 215-229.

Ruess, R.W., J.M. McFarland, L.M. Trummer, and J.K. Rohrs-Richey. 2009. Disease-mediated declines in N-fixation inputs by *Alnus tenuifolia* to early-successional floodplains in interior and south-central Alaska. Ecosystems 12: 489-502.

Synergistic Activities: Active in science education of Native high school students from coastal Yupik villages in western AK; co-leader AK SEEDS program; regular lectures at Fairbanks elementary schools and advisor to Fairbanks high school science programs; advisor to State (ADF&G), Native (Chevak Traditional Council), and Federal (BLM, Forest Service, AK Science Center) agencies within AK.

List of Collaborators in the Past 48 Months: M. Allen (UCR), B. Bond-Lamberty (UW), R.T. Bowyer (UI), D. Clark (UM), S. Collins (UNM), M.B. Coughenour (CSU), C. Giardina (USFS), S.T. Gower (UW), S. Hart (UCM), R.L. Hendrick (UGA), K. Kajtha (OSU), C. Litton (UH), C. Lovelock (Queensland), K. O'Connell (OSU), K. Pregitzer (MTU), J. Sedinger (UNR), J. Vogel (TTU), S. Wright (USDA)..

Advisors: Ph.D., M.K. Wali (The Ohio State Univ) ; Post-doc, S.J. McNaughton (Syracuse Univ)

Graduate Students/ Post-Doctoral Scientists Supervised (as chair): Current: Mike Anderson (Ph.D.,co-chair), Chris Babcock (Ph.D.), Kendra Calhoun (M.S.), Brian Heitz (Ph.D.), Michaela Swanson (M.S.), Tumi Traustason (Ph.D., co-chair). **Previous**: Kate Doran (Ph.D.), Claudia Ihl (Ph.D, co-chair), Ron Hendrick (Post-Doc), Kasey Klingensmith (Post-Doc), Beth Lenart (M.S., co-chair), Trish Loomis (M.S.), Jack McFarland (Ph.D.), Jennifer Mitchell (M.S.), Christa Mulder (Ph.D.), Dana Nossov (M.S.), Brian Person (Ph.D.), Dan Uliassi (M.S.), Amy Zacheis (Ph.D.).

Thomas A. Hanley

Team Leader of Boreal Ecology Cooperative Research Unit, Ecosystem Processes and Functions Program, USDA Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801-8626, phone 907-586-7805, thanley@fs.fed.us

EDUCATION

Arizona State University, Tempe, AZ: Wildlife Biology, B.S., 1973
Arizona State University, Tempe, AZ: Range Ecology, M.S., 1976
University of Washington, Seattle, WA: Forest Zoology, emphasis on herbivore-plant interactions, Ph.D., 1980

APPOINTMENTS

Professional:

Chief Wildlife Biologist and Team Leader (GS-15), Alaska Wildlife Habitat Team (1991 – 2007) and Boreal Ecology Cooperative Research Unit (2005-present), USDA Forest Service, Pacific Northwest Research Station, Juneau, AK, 1991 – present
Research Wildlife Biologist, USDA Forest Service, Pacific Northwest Research Station, Juneau, AK, 1980 – 1991
Wildlife Biologist, U.S. Dept. Interior, Bureau of Land Management, Cedarville, CA, 1976-1977

Current university affiliation:

Affiliate Professor, Department of Biology, Fisheries, and Wildlife, University of Alaska, Fairbanks, 1996 – present

PUBLICATIONS (87 total)

Most closely related to proposed project:

Butler, L.G., K. Kielland, T.S. Rupp, and T.A. Hanley. 2007. Interactive controls of herbivory and fluvial dynamics on landscape vegetation patterns on the Tanana River floodplain, interior Alaska. *Journal of Biogeography* 34:1622-1631.
Hanley, T.A. and J.C. Barnard. 1999. Spatial variation in population dynamics of Sitka mice in floodplain forests. *Journal of Mammalogy* 80:866-879.
Pollock, M.M., R.J. Naiman, and T.A. Hanley. 1998. Plant species richness in riparian wetlands — a test of biodiversity theory. *Ecology* 79:94-105.
Hanley TA. 1997. A nutritional view of understanding and complexity in the problem of diet selection by deer (Cervidae). *Oikos* 79:209-218.
Hanley, T.A., C.T. Robbins, A.E. Hagerman, and C. McArthur. 1992. Predicting digestible protein and digestible dry matter in tannin-containing forages consumed by ruminants. *Ecology* 73:537-541.

SYNERGISTIC ACTIVITIES

Chair of High Latitude Ecosystems Directorate and Member of National Committee, United States Man and the Biosphere Program (MAB), Washington, D.C., 1997 – 2000 (member of High Latitude Ecosystems Directorate since 1992).
United States' Representative to United Nations (UNESCO) MAB Northern Sciences Network, 1994 – 2000.

Jeremy B. Jones, Jr.

EDUCATION

San Francisco State University	Biology (Ecology)	B.S.	1988
Virginia Commonwealth University	Biology	M.S.	1990
Arizona State University	Zoology (Ecology)	Ph.D.	1994
Oak Ridge National Laboratory	Ecosystem Ecology	Postdoctoral	1995 – 1996

APPOINTMENTS

Associate Professor, University of Alaska Fairbanks, 2006 – present
Assistant Professor, University of Alaska Fairbanks, 2000 – 2006
Assistant Professor, University of Nevada, Las Vegas, 1996 – 2000
Global Change Distinguished Postdoctoral Fellow, Department of Energy, 1995 – 1996

RELEVANT PUBLICATIONS

Jones, J.B., K.C. Petrone, J.C. Finlay, L.D. Hinzman, and W.R. Bolton. 2005. Nitrogen loss from watersheds of interior Alaska underlain with discontinuous permafrost. Geophysical Research Letters 32:L02401, 10.1029/2004GL021734.

Betts, E.F., and J.B. Jones. 2009. Impact of wildfire on stream nutrient chemistry and ecosystem metabolism in boreal forest catchments of interior Alaska. Arctic, Antarctic, and Alpine Research 41:407-417. DOI: 10.1657/1938-4246-41.4.407.

Balcarczyk, K.L., J.B. Jones, R. Jaffé, and N. Maie. 2009. Stream dissolved organic matter bioavailability and composition in watersheds underlain with discontinuous permafrost. Biogeochemistry 94:255-270. DOI 10.1007/s10533-009-9324-x.

Clilverd, H.M., J.B. Jones, and K. Kielland. 2008. Nitrogen retention in the hyporheic zone of a glacial river in interior Alaska. Biogeochemistry 88:31-46. DOI 10.1007/s10533-008-9192-9.

Petrone, K.C., J.B. Jones, L.D. Hinzman, and R.D. Boone. 2006. Seasonal export of carbon, nitrogen and major solutes from Alaskan catchments with discontinuous permafrost. Journal of Geophysical Research – Biogeosciences:G02020, doi10.1029/2005JG000055.

SYNERGISTIC ACTIVITIES

1. Lead planning for the taiga domain for NEON.
2. Assisted the National Park Service with Inventory and Monitoring Program for the Artic National Parks and Preserves.
3. Participated on a planning team for a proposed Hydrologic Monitoring Facility to the National Science Foundation.
4. Instructor at Fisheries Field Camp for Alaska Native High School Students.
5. Served on the Executive Committee, the Program Committee for the 2006 annual meeting, and the Endowment Committee for the North American Benthological Society.

GRADUATE AND POST-GRADUATE ADVISORS

Leonard A. Smock, Virginia Commonwealth University; Stuart G. Fisher, Arizona State University; Nancy B. Grimm, Arizona State University; Patrick J. Mulholland, Oak Ridge National Laboratory

GRADUATE STUDENTS AND POST-DOCS SUPERVISED

Kevin Petrone (Ph.D., 2005), Jonathon O'Donnell (M.S., 2005), Emma Betts (M.S. 2006), Hannah Clilverd (M.S., 2007), Kelly Balcarczyk (M.S., 2008), Amanda Rinehart (Ph.D., In progress), Andrew Balser (Ph.D., In progress), Ban Abbott (Ph.D., In progress), Ann Olsson (Ph.D., In progress), Kurt Smart (Ph.D., In progress), Tamara Harms (post-doc, presently)

MICHELLE C. MACK
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a. Professional preparation

University of California-Berkeley, Ph.D. in Integrative Biology, 1998
The Evergreen State College, concurrent B.S. in Biology and B.A. in Literature, 1990

b. Appointments

2008-present	University of Florida, Department of Biology, Associate Professor
2002-2008	University of Florida, Department of Botany, Assistant Professor
2000-present	Research Associate, Institute of Arctic Biology (IAB), University of Alaska Fairbanks (UAF)
2000-2002	USDA Postdoctoral Fellow (NRICGP), IAB, UAF
1998-2000	NSF Postdoctoral Fellow in Biosciences Related to the Environment, IAB, UAF
1994-1997	NASA Global Change Graduate Fellow, Department of Integrative Biology, U.C.-Berkeley

c. Publications

Five related publications

Mack, M.C., K.K. Treseder, K.L. Manies, J.W. Harden, E.A.G. Schuur, J.G. Vogel, J.T. Randerson, and F.S. Chapin, III. 2008. Recovery of aboveground plant biomass and productivity after fire in mesic and dry black spruce forests of Interior Alaska. Ecosystems 11 (2): 209-225.

Bret-Harte M.S., M.C. Mack, G.R. Goldsmith, D.B. Sloan, G.R. Shaver, P.M. Ray, Z. Biesinger, and F.S. Chapin, III. 2008. Plant functional types do not predict biomass responses to removal and fertilization in Alaskan tussock tundra. Journal of Ecology, 96 (4): 713-726.

Nowinski, N., S.E. Trumbore, E.A.G. Schuur, M.C. Mack, and G.R. Shaver. 2008. Nutrient addition prompts rapid destabilization of organic matter in an arctic tundra ecosystem. Ecosystems 11 (1): 16-25.

Goetz, S.J., M.C. Mack, K.R. Gurney, J.T. Randerson and R.A. Houghton. 2007. Ecosystem responses to future climate change and fire disturbance at northern high latitudes: observations and model results contrasting northern Eurasia and North America. Environmental Research Letters 2 (045031):1-9.

Mack, M.C., E.A.G. Schuur, M.S. Bret-Harte, G.R. Shaver, and F.S. Chapin III. 2004. Carbon storage in arctic tundra reduced by long-term nutrient fertilization. Nature 431: 440-443.

d. Synergistic Activities:

- I am a co-PI the Bonanza Creek and a senior scientists on the Arctic Long Term Ecological Research grants.
- I have chaired the graduate committees of seven students and advised four postdoctoral researchers.
- I mentored a High School Earth Sciences teacher and a Middle School science teacher in arctic research as part of the NSF-funded Teachers and Researchers Exploring and Collaborating Program, which is managed by ARCUS. 2004, 2006.
- I have sponsored 14 NSF Research Experience for Undergraduate student participants in summer research projects at the Bonanza Creek and Arctic LTER sites, in the Russian Far East and at La Selva Research Station, Costa Rica. 1999-2006.

Doctoral advisor: Dr. Carla D'Antonio, University of California-Berkeley.
Postdoctoral advisor: Dr. F. Stuart Chapin III, University of Alaska.

A. David McGuire

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EDUCATION

Ph.D.	University of Alaska Fairbanks, Biology	1989
M.S.	University of Alaska Fairbanks, Biology	1983
M. Engineering	Cornell University, Electrical Engineering	1977
B.S.	Cornell University, Electrical Engineering	1976

CURRENT POSITION

Professor of Ecology in Department of Biology and Wildlife/Institute of Arctic Biology, University of Alaska Fairbanks (2003 – present).

PROFESSIONAL ACTIVITIES (last 5 years)

Board of Editors: *Ecological Applications* and *International Journal of Wildland Fire*.

Co-Chair: U.S. Arctic Research Commission study and report titled *Scaling Studies in Arctic System Science and Policy Support: A Call-to-Research*.

Member: Federal Advisory Committee Author Team for U.S. Global Change Research Program Report on *Global Climate Change Impacts in the United States*; Interagency Advisory Committee on Department of Transportation Federal Highway Administration Report on *Regional Climate Change Effects: Useful Information for Transportation Agencies*; Carbon Cycle Science Steering Group for U.S. Global Change Research Program; Long Term Ecological Research Network Executive Board; Study of Environmental Arctic Change (SEARCH); Arctic Community-wide Hydrological Analysis and Monitoring Program (Arctic-CHAMP).

FIVE RELATED PUBLICATIONS (115 peer reviewed publications, 22 book chapters)

McGuire, A.D., R. Ruess, A. Lloyd, J. Yarie, J. Clein, and G. Juday. 2010. Vulnerability of white spruce tree growth in interior Alaska in response to climate variability: Dendrochronological, demographic, and experimental perspectives. *Canadian Journal of Forest Research*. In press.

McGuire, A.D., L.G. Anderson, T.R. Christensen, S. Dallimore, L. Guo, D.J. Hayes, M. Heimann, T.D. Lorenson, R.W. Macdonald, and N. Roulet. 2009. Sensitivity of the carbon cycle in the Arctic to climate change. *Ecological Monographs* 79:523-555.

Yi, S., A.D. McGuire, J. Harden, E. Kasaschke, K. Manies, L. Hinzman, A. Liljedahl, J. Randerson, H. Liu, V. Romanovsky, S. Marchenko, and Y Kim. 2009. Interactions between soil thermal and hydrological dynamics in the response of Alaska ecosystems to fire disturbance. *Journal of Geophysical Research – Biogeosciences* 114, G02015, 20 pages, doi:10.1029/2008JG000841.

Euskirchen, E.S., A.D. McGuire, T.S. Rupp, F.S. Chapin III, and J.E. Walsh. 2009. Projected changes in atmospheric heating due to changes in fire disturbance and the snow season in the western Arctic, 2003 – 2100. *Journal of Geophysical Research – Biogeosciences* 114, G04022, 15 pages, doi:10.1029/2009JG001095.

Euskirchen, E.S., A.D. McGuire, F.S. Chapin III, S. Yi, and C.C. Thompson. 2009. Changes in vegetation in northern Alaska under scenarios of climate change 2003-2100: Implications for climate feedbacks. *Ecological Applications* 19:1022–1043.

EUGÉNIE EUSKIRCHEN

a) Professional Preparation

Marymount College, Tarrytown, NY	Mathematics; B.S., 1994
Johns Hopkins Univ., Baltimore, MD	Mathematical Sciences; M.S., 1997
Michigan Technological Univ., Houghton, MI	Forest Science; Ph.D., 2003
Univ. of Alaska, Fairbanks, AK	Postdoctoral Fellow, 2004 – 2006

b) Appointments:

5/2009- present: Research Assistant Professor, University of Alaska Fairbanks, Fairbanks, AK
3/2006 – 4/2009: Research Associate, University of Alaska Fairbanks, Fairbanks, AK
6/1997-6/1998: Hydrologist, U.S. Geological Survey, Baltimore, MD
6/1994-8/1995: Environmental modeling/analyst, Argonne National Laboratory, Argonne, IL

c) Selected Publications

5 most closely related publications:

1. **E.S. Euskirchen**, A.D. McGuire, T.S. Rupp, F.S. Chapin III. 2009b. Projected changes in atmospheric heating due to changes in fire disturbance and the snow season in the western Arctic, 2003 – 2100, Journal of Geophysical Research-Biogeosciences,
2. **Euskirchen, E.S**., A.D. McGuire, F.S. Chapin III, S. Yi, and C.C. Thompson. 2009a. Changes in vegetation in northern Alaska under scenarios of climate change 2003-2100: Implications for climate feedbacks. *Ecological Applications*.
3. **Euskirchen, E.S**., A.D. McGuire, F.S. Chapin III. 2007. Energy feedbacks of northern high latitude ecosystems to the climate system due to reduced snow cover during 20th century warming. *Global Change Biology.*
4. **Euskirchen, E.S**., A.D. McGuire, D.W. Kicklighter, Q. Zhuang, J.S. Clein, R.J. Dargaville, D.G. Dye, J.S. Kimball, K.C. McDonald, J.M. Melillo, V.E. Romanovsky, N.V. Smith. 2006. Recent shifts in the dynamics governing growing season length and productivity in terrestrial high-latitude ecosystems. *Global Change Biology* 12:731-750.
5. **Euskirchen, E.S.**, K.S. Pregitzer, J. Chen. 2006. Carbon fluxes in a young naturally regenerating jack pine ecosystem. *Journal of Geophysical Research*, doi: 10.1029/2005JD005793.

d) Synergistic Activities:

- National Science Foundation, Ecosystem Studies panelist (invited, 2009)
- Peer-review grant panelist (invited, 2006, 2007[2], 2009) for the Department of Energy (DOE) National Institute of Climate Change Research (NICCR)
- Near-Surface Processes Community of Practice in the Arctic, Arctic Research Consortium of the U.S. (2006 – 2007)
- **Manuscript reviewer**: *Agricultural and Forest Meteorology* (2005,2006*); Canadian Journal of Forest Research* (2005)*; Climate Research* (2009) *Computing in Science and* Engineering (2007); *Earth Interactions* (2004, 2006)*; Ecography* (2005)*; Ecosystems (*2000, 2006, 2007); *Ecological Modelling* (2003); *Forest Ecology and Management* (2000, 2003[2], 2004[4], 2005[2], 2006[3]); *Global Change Biology* (2008, 2009[2]); *Global and Planetary Change* (2005, 2007)*; Journal of Applied Meteorology* (2003)*; Journal of Geophysical Research-Atmospheres* (2006); *Journal of Geophysical Research-Biogeosciences* (2007[2]), *Landscape Ecology* (2003); *Mitigation and Adaptation Strategies for Global Change* (2005); *Oikos* (2000), *Proceedings of the National Academy of Sciences* (2009); *Remote Sensing of the Environment* (2005), *Southeastern Naturalist* (2005)

Jennifer W. Harden
U.S. Geological Survey
345 Middlefield Rd ms 962
Menlo Park, CA 94025

EDUCATION AND ACTIVITIES

Ph.D., Soil Resource Conservation, Univ. of California, Berkeley, CA (1982)
M.S., Soil Science, Univ. of California, Berkeley, CA (1979)
B.S., Soil Science, Univ. of California, Berkeley, CA (1976)

President Biogeosciences Section AGU 2010-2012
President-elect Biogeosciences Section AGU 2007-2009
Board member, U.S. Permafrost Association 2007-2008

Project chief U.S. Geological Survey Global Change Program: Fate of Carbon on Alaskan Landscapes 2000 to present

Co-Investigator NSF Geosciences Collaborative Research EAR-0630249: Impact of Permafrost Degradation on Carbon and Water in Boreal Ecosystems.. Lead PI: Qianlai Zhuang, Purdue University 2007 – 2011.

Participant and founding member: National Soil Carbon Network

FIVE RELEVANT PUBLICATIONS

Harden, J.W., Fuller, C.C., Wilmking, M., Meyers-Smith, I.H., Trumbore, S.E., and Bubier, J. 2008. The fate of terrestrial carbon following permafrost degradation: detecting changes over recent decades. Proceedings of the Ninth International Conference on Permafrost, June 29 – July 3, 2008. Kane, D.L. and Hinkel, K.M. (Eds.) Institute of Northern Engineering, University of Alaska Fairbanks. p. 649 – 654.

Meyers-Smith, Isla, McGuire, A. David , Harden, J. W., and Chapin III, F. Stuart 2008. The influence of disturbance on carbon exchange in a permafrost collapse and adjacent burned forest. Jour. Geophys. Research. 112, GO4017,11p, DOI 10.1029/2007JG000423

Harden, J.W., Manies, K.L., Neff, J.C., and Turetsky, M.R. 2006. Effects of wildfire and permafrost on soil organic matter and soil climate in interior Alaska. Global Change Biology 12: 1-13, doi: 10.1111/j.1365-2486.2006.01255.x.

Harden, J.W. , S.E. Trumbore, B.J. Stocks, A. Hirsch, S.T. Gower, K.P. O'Neill, and E.S. Kasischke. 2000. The role of fire in the boreal carbon budget. Global Change Biology 6, suppl.1, 174-184.

Goulden, M.L., Wofsy, S.C., Harden, J.W., Trumbore, S.E., Crill, P.M., Gower, S.T., Fries, T., Daube, B.C., Fan, S.M., Sutton, D.J. Bazzaz, A., and Munger, J.W. 1998. Sensitivity of boreal forest carbon to soil thaw. Science 279, 214-217.

Teresa Nettleton Hollingsworth

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PNW Research Station USDA Forest Service **phone: (907) 474-2424**
University of Alaska Fairbanks **fax : (907) 474-6251**
P.O. Box 756780 Fairbanks, AK 99775 **email:** thollingsworth@fs.fed.us

EDUCATION:

2000- 2004 **University of Alaska Fairbanks-** Ph.D., Biological Sciences: Biology

1998-2000 **Lancaster University, England-** Masters of Science, Biology

1993-1997 **University of Colorado, Boulder-** B.A., EPO Biology

PROFESSIONAL EXPERIENCE:

- Research Ecologist, USFS PNW Research Station, Boreal Ecology Cooperative Research Unit (January 2005-present)
- Affiliate Faculty Member, Department of Biology and Wildlife, School of Natural Sciences and Mathematics (2006-present)
- Affiliate Assistant Professor of Forest Ecology, Department of Forest Sciences, School of Natural Resources and Agricultural Science, University of Alaska Fairbanks (April 2005-present)

RECENT GRANTS AND FELLOWSHIPS:

- USGS Yukon Basin Initiative (Co PI) (2009-2011)
- PNW Cooperative Agreement with University of Alaska Fairbanks: "Assessing the impact of Climate Change in Alaska: Current trends and future projections for forests" (Federal Principal Investigator) (2009)
- Joint Fire Science Program (Federal PI) (2005-2006)
- National Science Foundation, Long-Term Ecological Research Program (Senior Investigator) (2004-2008)

PROFESSIONAL SERVICES AND MEMBERSHIPS:

- 18 month term member of the PNW Research Station Leadership Team (December 2005-July 2007)
- Member of the Bonanza Creek LTER Executive Committee (January 2005-present)
- Manuscript reviewer for Arctic and Alpine Research, Forest Ecology and Management, Canadian Journal of Botany, Silvia Fennica, Ecology, Ecological Applications, Conservation Biology, Canadian Journal of Forest Research, Ecosystems

PUBLICATIONS:

Hollingsworth, T.N, A.H. Lloyd, D.R Nossov, R.W. Ruess, B.A. Charlton, and K. Kielland (in press). Twenty-five years of change in understory plant communities along the Tanana River, Alaska: Disentangling the relationship between successional processes, past legacies, and current climate trends. Canadian Journal of Forest Research

Johnstone, J.F., T.N. Hollingsworth, F.S Chapin III. (2009). Changes in fire regime break the legacy lock on successional trajectories in Alaskan boreal forest. Global Change Biology *doi:* 10.1111/j.1365-2486.2009.02051.x

Bernhardt, E.L, T.N. Hollingsworth, F.S. Chapin III, and L.A. Viereck (in press). Fire severity mediates climate-driven shifts in understory composition of black spruce stands of interior Alaska. Journal of Vegetation Science.

Hollingsworth, T.N., E.A.G. Schuur, F.S. Chapin III, and M.D. Walker (2008). Plant community composition as a predictor of regional soil carbon storage in the boreal black spruce ecosystem. Ecosystems 11(4): 629-642.

Gould, W.A., G. González, A.T. Hudak, T.N Hollingsworth, and Hollingsworth J. (2008). Forest structure and downed woody debris in boreal, temperate, and tropical forest fragments. Ambio. 37(7-8): 577-587.

Biographical Sketch - Jill F. Johnstone

Professional Preparation

Middlebury College (USA)	Northern Studies	B.A. 1992
University of British Columbia (Canada)	Geography	M.Sc. 1995
University of Alaska Fairbanks (USA)	Biology	Ph.D. 2003

Appointments

2006-current - Assitant Professor, Department of Biology, University of Saskatchewan
2005-current - Research Associate, Institute of Arctic Biology, University of Alaska Fairbanks
2003-2006 – NSERC post-doctoral fellow, Geography & Env. Studies, Carleton University and Yukon College, Whitehorse, YT
2004 - Sessional instructor, Division of Arts and Science, Yukon College
1996-1999 - Environmental Consultant, Cassiopeia Research Services, Whitehorse, YT

5 Recent & Relevant Publications

Johnstone, J.F. , Hollingsworth, T.K.N., Chapin, F.S., III, and Mack, M.C. (2010) Changes in fire regime break the legacy lock on successional trajectories in Alaskan boreal forest. *Global Change Biology*, in press.

Johnstone, J.F., Boby, L., Tissier, E., Mack, M.C., Verbyla, D.L., and Walker, X. (2009) Post-fire seed rain of black spruce, a semi-serotinous conifer, in forests of interior Alaska. *Canadian Journal of Forest Research* 39: 1575-1588.

Johnstone, J.F. and Chapin, F.S., III. (2006) Fire interval effects on successional trajectory in boreal forests of Northwest Canada. *Ecosystems* 9: 268-277.

Johnstone, J.F. and Chapin, F.S., III. (2006) Effects of soil burn severity on patterns of post-fire tree recruitment in boreal forests. *Ecosystems* 9: 14-31.

Johnstone, J.F., Chapin, F.S., III, Foote, J., Kemmet, S., Price, K., and Viereck, L. (2004) Decadal observations of tree regeneration following fire in boreal forests. *Canadian Journal of Forest Research* 34: 267-273.

Synergistic Activities:

Teaching and Training
- Developed a new third-year, undergraduate course in Community Ecology (BIOL 373) that focuses on inquiry-based, writing-intensive learning (2009).
- Organized and led a 3-day workshop on local plant use for the remote northern community of Old Crow, Yukon, including production of an educational workbook (2008).
- Committed to the mentoring and training of women and minorities in natural science (currently supervising 6 female graduate students, including 1 minority student).

Collaborators & Other Affiliations:

Collaborators (non-LTER): A. Bedard-Haughn (U. Saskatchewan), K. Harper (Dalhousie U.), S. Kokelj (Indian and Northern Affairs Canada), E. McIntire (U. Laval), V. Loewen (Yukon Gov.)
Graduate and Postdoctoral Advisors: C.R. Burn (Carleton University); F.S. Chapin, III (University of Alaska Fairbanks); G.H.R. Henry (University of British Columbia)
Graduate students advised: K. Allen, C. Brown, S. Pieper, A. Shenoy, E. Tissier, N. Wunderlich, J. Viglas (7 in total)

Curriculum vitae: **Glenn Patrick Juday**

Present Position and Address:
Professor of Forest Ecology, Department of Forest Sciences, School of Natural Resources and Agricultural Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775
Phone: 907-474-6717, Email: **gpjuday@alaska.edu**

Education: B.S. *summa cum laude*, 1972, Forest Management, Purdue University, Ph.D., 1976, Plant Ecology, Oregon State University, Post-Doctoral Fellowship in Environmental Affairs, 1976-1977, (Rockefeller Foundation) Oregon State University.

Previous Professional Appointment: Research Ecologist (GS-13), USDA Forest Service 1978-1981.

Recent and Relevant Publications

Juday, Glenn Patrick. 2009. Boreal Forests and Climate Change. Pp. 75-84, In: Oxford Companion to Global Change. Oxford University Press. 684 pp. ISBN: 978-0-19-532488-4.

Juday, G.P. (Lead Author), Barber, V.; Vaganov, E.; Rupp, S.; Sparrow, S.; Yarie, J.; Linderholm, H. (Contrib. Authors), and numerous consulting authors. 2005. Forests, Land Management, Agriculture, Chapter 14 Pp 781-862, In: Arctic Climate Impact Assessment. Arctic Council. *Cambridge University Press*. ISBN 978-0-521-86509-8.

Barber, V.A., G.P. Juday and B.P. Finney. 2004. Reconstruction of Summer Temperatures in Interior Alaska: Evidence for Changing Synoptic Climate Regimes. *Climatic Change* 63 (1-2): 91-120.

Juday, G.P., Barber, V., Rupp S., Zasada, J., Wilmking M.W. 2003. A 200-year perspective of climate variability and the response of white spruce in Interior Alaska. Chapter 12 Pp. 226-250. In: Greenland, D., Goodin, D., and Smith, R. (editors). Climate Variability and Ecosystem Response at Long-Term Ecological Research (LTER) Sites. Oxford University Press.

Barber, V.A., G.P. Juday, B.P Finney. 2000. Reduced growth of Alaska white spruce in the twentieth century from temperature-induced drought stress. Nature 405: 668-673.

RESEARCH SUMMARY

1 journal article in press, 1 proceedings chapter accepted, 1 journal article in review, 1 book chapter in review, 1 popular article in review, 33 published journal articles and other peer-reviewed publications (11 from 2005 or later), 33 published papers in peer or editor-reviewed proceedings (4 from 2005 or later), 5 other reviewed publications, 30 contract and other publications (2 from 2005 or later), 107 published abstracts (24 from 2005 or later), 22 reports on Research Natural Areas.

Recent and Relevant Synergistic Activities

Invited Testimony to U.S. House of Representatives, Committee on Science and Technology. Hearing on 10/17/2007 - Disappearing Polar Bears and Permafrost: Is a Global Warming Tipping Point Embedded in the Ice? 4 pp. http://science.house.gov/publications/Testimony.aspx?TID=8659, and U.S. House Select Committee on Energy Independence and Global Warming, Sep. 25, 2007.

U.S. Senate consultations. Individual briefing of 5 members of the U.S. Senate on climate change issues based on research results (Senators Lisa Murkowski, John McCain, Susan Collins, Lindsey Graham, and Hilary Clinton).

Science Advisor to PBS Television episode “Hot Times in Alaska,” in Scientific American Frontiers Program, Chedd-Angier Productions, Original broadcast May 15, 2004.

Certificate of recognition for outstanding accomplishments of Forest Ecology Working Group (WG), Society of American Foresters (SAF), presented November 17, 2000.

Kelmelis, J., Becker, E., Kirtland, S. 2005. Notes from an International Workshop on the Foreign Policy Implications of Arctic Warming, Arlington, VA, January 27-28, 2005. USGS Open-File Report 2005-1447, 46 p. (G. Juday participation under Chatham House Rule)

ERIC S. KASISCHKE

Professor
Department of Geography
University of Maryland
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College Park, MD

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FAX: (301) 314-9299

EDUCATION

BS: Natural Resources, The University of Michigan, 1974
MS: Remote Sensing, The University of Michigan, 1980
PhD: Remote Sensing/Forest Ecology, The University of Michigan, 1992

EXPERIENCE

Dr. Kasischke's research focuses on understanding processes controlling ecosystem processes and carbon cycling in boreal forests, with a specific focus on the effects of fire and climate change. He has carried out research in this area since the early 1990s. He has been the principal investigator on numerous interdisciplinary, multi-institutional research projects funded by NASA and EPA, dating back to his role as a PI on the NASA SIR-C project in the late 1980s/early 1990s. His research involves applications of satellite remote sensing data, field studies, and development of theoretical models of biogeochemical and ecosystem processes, including models to estimate trace gas and particulate emissions from biomass burning. His current research involves three NASA funded projects on the impacts of fires in boreal forests and peatlands. As part of his field research, he has been a Senior Investigator for the Bonanza Creek Long Term Ecological Research Site funded through NSF and the USFS since. He is a member of the U.S. Carbon Cycle Scientific Steering Group.

PUBLICATIONS

Dr. Kasischke has made well over 100 presentations at scientific and professional meetings. He has authored or co-authored 98 articles in refereed journals and 35 book chapters. He has also published two books. Representative publications include:

Balshi, M.S., A.D. McGuire, Q. Zhuang, J. Mellilo, D.W. Kicklighter, **E.S. Kasischke,** C. Wirth, M. Flannigan, J. Harden, J.S. Clein, T.J. Burnside, J. McAllister, W. Kurz, M. Apps, and A. Shvidenko, The role of historical fire disturbance in the carbon dynamics of the pan-boreal region: A process-based analysis, *J.Geophys. Res,112,* G02029, doi:10.1029/2006JG000380, 2007.

Hoy, E.E., N.H.F. French, M.R. Turetsky, S.N. Trigg, and **E.S. Kasischke**, Evaluating the potential of the normalized burn ratio and other spectral indices for assessment of fire severity in Alaskan black spruce forests, *Int. J. Wildland Fire*, *17,* 500-514, 2008.

Kane, E.S., **E.S. Kasischke**, D.W. Valentine, M.R. Turetsky, and A.D. McGuire, Topographic influences on wildfire consumption of soil organic carbon in black spruce forests of interior Alaska: implications for black carbon accumulation, *J. Geophys Res.., 112,* G03017, doi:10.1029/2007JG000458, 2007

Kasischke, E.S., and M.R. Turetsky, Recent changes in the fire regime across the North American boreal region- spatial and temporal patterns of burning across Canada and Alaska, *Geophys. Res. Lett.*, *33*, L09703, doi:10.1029/2006GL025677, 2006.

Kasischke, E.S. et al., Influences of boreal fire emissions on Northern Hemisphere atmospheric carbon and carbon monoxide, *Glob. Biogeochem. Cycles*, 19,GB1012, doi:10.1029/2004GB002300, 2005.

Biographical Sketch - Knut Kielland

Institute of Arctic Biology
University of Alaska Fairbanks
Fairbanks, Alaska 99775-0180
Phone: 907/474-7164, Fax: 907/474-6967
email: ffkk@.uaf.edu

Education

Ph.D.	1990	University of Alaska Fairbanks
B.S.	1982	University of Alaska Fairbanks

Current position

Associate Professor, Institute of Arctic Biology, UAF

External Reviewer

1994 – present: NSF Ecosystem Studies, Ecological and Evolutionary Physiology Program, Polar Programs, CAREER, Research Council of Norway, National Geographic Society, USDA, US Civilian Research and Development Foundation

Peer Reviewer

American Naturalist, Biogeochemistry, Ecology, Ecology Letters, Ecosystems, Geophysical Research Letters, Global Change Biology, Journal of Animal Ecology Journal of Wildlife Management, Nature, Oecologia, Oikos, Plant and Soil, Quarterly Review of Biology, Wildlife Biology, Wildlife Society Bulletin

Five Most Relevant Publications:

Angell, A. and K. Kielland. 2009. Establishment and growth of white spruce on a boreal forest floodplain: interactions between microclimate and mammalian herbivory. *Forest Ecology and Management* 258:2475-2480

Näsholm,T., K. Kielland and U. Ganeteg. 2009. Uptake of Organic Nitrogen by Plants. *New Phytologist (Tansley Review)* 182:31-48

Rattenbury, K., K. Kielland, G. Finstad, and W. Schneider. 2009. Reindeer herding, weather, and environmental change on the Seward Peninsula, Alaska. *Polar Record* 28: 71-88

Butler, L.G., K. Kielland. 2008. Acceleration of vegetation turnover and element cycling by mammalian herbivory in riparian ecosystems. *Journal of Ecology* 96:136-144.

Kielland, K., J.W. McFarland, R.W. Ruess, and K. Olson. 2007. Rapid organic nitrogen cycling in taiga forest ecosystems. *Ecosystems* 10:360-368.

Kielland, K., J.P. Bryant, and R.W. Ruess. 2006. Mammalian herbivory, ecosystem engineering, and ecological cascades in taiga forests. Pages 211-226, In: F.S. Chapin, III, M.W. Oswood, K. Van Cleve, L. Viereck, and D. Verbyla (editors), *Alaska's Changing Boreal Forest*, Oxford University Press, New York, NY.

Synergistic activities:

Science presentations and science curriculum development in local K-12 schools, Fairbanks North Star Borough School District (USDA and NSF grant supported). Technology transfer and socio-economic development outreach in rural, native communities, northwest Alaska (NSF grant supported).

Scientific Collaborators

L. Edenius, G. Ericsson, I-L Persson, D.L. Jones, J. Forbey, Z. Feng

Graduate Student Trained: (*Current*) 4 M.S. students, 1 Ph.D.
(*Previous*) * M.S. students, 1 Ph.D.

BIOGRAPHICAL SKETCH – GARY PETER KOFINAS

Professional Preparation:

University of British Columbia, Vancouver, B.C., Canada. Ph.D., Interdisciplinary Studies in Resource Management Science.

Antioch/New England Graduate School, Keene, N.H., M.S.T., Environmental Studies.

University of North Carolina Greensboro. Greensboro, N.C., B.A., Philosophy.

Appointments:

Associate Professor of Resource Policy and Management; joint appointment with the Department of Resources Management and Institute of Arctic Biology, University of Alaska Fairbanks; (August 2002 – 2007 as Assistant Professor)

Research Assistant Professor of Public Policy, Institute of Social and Economic Research, University of Alaska Anchorage. (March, 2000-August 2002).

Senior Fellow, Institute of Arctic Studies, Dartmouth College (August 2001 – August 2002; Research Fellow from October, 1997-August 2001).

5 most relevant publications:

Berman, Matt, and Gary Kofinas, "Hunting for Models: Rational Choice and Grounded Approaches to Analyzing Climate Effects on Subsistence Hunting in an Arctic Community" (2004) Ecological Economics Vol. 49. 31-46

Kofinas, Gary, "Hunters and Researchers at the Co-management Interface: Emergent Dilemmas and the Problem of Legitimacy" (2005) *Anthropologica*, Vol. 47 No 2, pp 179-196. Special issue, "Co-Management and Indigenous Communities."

Chapin III, F. S., G. P. Kofinas, and C. Folke, editors. 2009. Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World. Springer-Verlag, New York. ISBN: 978-0-387-73032-5

Kruse, J.A., R.G. White, H.E Epstein, B. Archie, M.D. Berman, S.R. Braund, F.S. Chapin III, J. Charlie Sr., C.J. Daniel, J. Eamer, N. Flanders, B. Griffith, S. Haley, L. Huskey, B. Joseph, D.R. Klein, G.P. Kofinas, S.M. Martin, S.M. Murphy, W. Nebesky, C. Nicolson, D.E. Russell, J. Tetlichi, A. Tussing, M.D. Walker, O.R. Young, (2004) "Modeling Sustainability of Arctic Communities: An Interdisciplinary Collaboration of Researchers and Local Knowledge Holders," *Ecosystems*, Volume 7: 1-14

Kofinas, Gary with Old Crow, Aklavik, Fort McPherson, and Arctic Village (2002) "Community Contributions to Ecological Monitoring: Knowledge Co-Production in the US-Canada Arctic Borderlands" in *Indigenous Observations of Environmental Change,* editors I. Krupnik and D. Dyanna. ARCUS. 54-92.

Synergistic Activities:

- Director/PI, Resilience and Adaptation IGERT Program at UAF; August 2007-present; Coordinator, Resilience and Adaptation IGERT Program August 20027-2007.
- Science Technical Advisory Group member; North Slope Science Initiative, Alaska.
- Leader, "Indigenous Societies and Social-Ecological Resilience Working Group," Resilience Alliance.

Recent collaborators: M. Berman (UAA), S. Chapin III, (UAF), B. Forbes, (Arctic Centre), B. Griffith (UAF), K. Klokov (St Petersburg State, C. Nicolson (UMA.), D. Russell (Environment Canada), C.Gerlach (UAF), S.Rupp (UAF).

Graduate students & post docs. C. Meek; J. Powell, A. Bali, M.Okada, J. Guzzetti; A. Butler, S. BurnSilver; S. Backensto, E. Robins.

Curriculum Vitae **MARY BETH LEIGH**

Institute of Arctic Biology
P.O. Box 757000, University of Alaska Fairbanks, Fairbanks, AK 99775-7000
Tel. (907) 474-6656 Fax (907) 474-6967 Email mbleigh@alaska.edu

(i) Professional Preparation:

Postdoctoral 2003-2006	Microbial Ecology	Michigan State University
Postdoctoral 2004	Microbial Ecology	CEH Oxford, UK
Ph.D. 2003	Microbiology	University of Oklahoma
M.S. 1997	Botany	University of Oklahoma
B.F.A. 1994	Modern Dance, Minor in Botany	University of Oklahoma

(ii) Academic Positions:

Assistant Professor of Microbiology, Institute of Arctic Biology, Department of Biology and Wildlife, University of Alaska Fairbanks, Aug. 2006 – present.

(iii) Publications (*5 most closely related):*

1) Larsen, T., D.L. Taylor, **M.B. Leigh** and D.M. O'Brien. 2009. Stable isotope fingerprinting: a novel method for identifying plant, fungal or bacterial origins of amino acids. *Ecology 90(12):3526–3535*
2) **Leigh, M.B.**, D.L. Taylor and J. Neufeld. 2010. Clone libraries of ribosomal RNA gene sequences for characterization of bacterial and fungal communities. *In* Handbook of Hydrocarbon and Lipid Microbiology, Vol. 5, p 3969-3993. Springer-Verlag, Berlin.
3) Uhlik, O., K. Jecna, **M. B. Leigh**, M. Mackova, T. Macek· 2009. DNA-based stable-isotope probing: a link between community structure and function. *Science of the Total Environment* 407(12):3611-9
4) Cardenas, E., **M.B. Leigh**, W.-M. Wu, J. Carley, C. Criddle, T.L. Marsh and J.M. Tiedje. 2008. Microbial communities in contaminated sediments, associated with bioremediation of uranium to submicromolar levels. *Applied and Environmental Microbiology* 74(12):3718-29
5) **Leigh, M.B.,** V.H. Pellizari, O. Uhlik, R. Sutka, J. Rodrigues, N.E. Ostrom, J. Zhou and J.M. Tiedje. 2007. Biphenyl-utilizing bacteria and their functional genes in a pine root zone contaminated with polychlorinated biphenyls (PCBs). *ISME Journal* 1:134-148.

(iv) Synergistic Activities:

- Editorial board of *Applied and Environmental Microbiology*
- Ad hoc reviewer of manuscripts for journals: *Proceedings of the National Academy of Sciences*, *Environmental Science and Technology, Applied and Environmental Microbiology, Microbial Ecology, ISME Journal, Biodegradation, Cold Regions Science and Technology, Food Technology and Biotechnology Journal*, *International Journal of Phytoremediation.*
- Faculty sponsor for student chapter of American Society for Microbiology Alaska
- Review panelist for proposals for U. S. Department of State Science Center Programs and David L. Boren National Security Education Program (NSEP) Fellowships.
- President of the Alaska Branch of the American Society for Microbiology (2010)

Andrea H. Lloyd (lloyd@middlebury.edu)
Department of Biology, Middlebury College
Middlebury VT 05753
802-443-3165 (voice)/ 802-443-2072 (fax)

(a) Professional Preparation

Degree	**Year Awarded**	**Institution**	**Major**
B.A.	1989	Dartmouth College	Geography
M.S.	1993	University of Alaska	Biology & Wildlife
Ph.D.	1996	University of Arizona	Ecology & Evolutionary Biology

(b) Appointments

2009-present Professor, Department of Biology, Middlebury College, VT
2003-2009 Associate Professor, Department of Biology, Middlebury College, VT
1996-2003 Assistant Professor, Department of Biology, Middlebury College, VT

(c) Publications

5 most closely related publications

McGuire, A.D., R.W. Ruess, A.H. Lloyd, J. Yarie, J.S. Clein, G.P. Juday. In press. Vulnerability of White Spruce Tree Growth in Interior Alaska in Response to Climate Variability: Dendrochronological, Demographic, and Experimental Perspectives Canadian Journal of Forest Research.

Lloyd, A.H. and A.G. Bunn (2007). Response of the circumpolar boreal forest to 20th century climate variability. Environmental Research Letters.2 045013. doi:10.1088/1748-9326/2/4/045013

Lloyd, A. H., M. E. Edwards, B. P. Finney, J. Lynch, V. A. Barber, and N. Bigelow. (2006) Development of the boreal forest. Pages 62-78 *in* F. S. Chapin, III, M. Oswood, K. Van Cleve, L. Viereck, and D. Verbyla, editors. Alaska's Changing Boreal Forest. Oxford University Press, Oxford.

Lloyd, A.H., C.L. Fastie, and H. Eisen (2007). Fire and substrate interact to control the northern range limit of black spruce (*Picea mariana*) in Alaska. Canadian Journal of Forest Research. 37(12): 2480-2493.

Lloyd, A.H. and C.L. Fastie (2002). Spatial and temporal variability in tree growth and climate response of treeline trees in Alaska. Climatic Change. 52:481-509.

(d) Synergistic activities

- *Education:*
  - Involvement of undergraduate students, particularly women, in Arctic research. Three students (all women) have completed honors theses based on fieldwork they conducted while working as an RA on my existing/past projects in Alaska. Several additional undergraduate students have worked as research assistants on LTER-funded research projects.
  - Data from LTER and related projects have been used to develop a boreal forest module for BIOL 230, global change biology, which I teach at Middlebury College. The module provides students with an opportunity to use real data to conduct hypothesis-testing around questions of climate change impacts on the boreal forest.
  - Participation in K-12 education through collaboration with Amy Clapp, science teacher at Salisbury Community School. 5th graders in Salisbury, VT, and Zhiganks, Russia are conducting simultaneous analysis of tree ring data from the two locations. Students will then compare results, as part of learning about climate change and biomes of the world.
- *Service to the broader scientific community:*
  - Member of the ARCUS (Arctic Research Consortium of the U.S.) Board of Directors, and have been involved in a variety of science planning activities, including organizing the upcoming State of the Arctic meeting (March, 2010) and serving on a subcommittee of the SEARCH SSC to write a white paper on understanding Arctic Change.

CHRISTA P.H. MULDER

A. Professional Preparation

- Swedish University of Agricultural Sciences, Umeå, Sweden. Post-doctoral fellow, BIODEPTH (Biodiversity and Ecosystem Processes in Terrestrial Herbaceous Systems) project, 1996-1998.
- University of Alaska Fairbanks, Alaska, USA. Ph.D. in Biology, 1997.
- Queen's University, Kingston, Ontario, Canada. M.Sc. in Biology, 1991.
- Bates College, Lewiston, Maine, USA. B.A., High Honors in Biology, 1988.

B. Professional Appointments:

- Associate Professor, Institute of Arctic Biology and Department of Biology and Wildlife, University of Alaska Fairbanks, U.S.A. (July 2006- present).
- Assistant Professor, Department of Biology & Wildlife and Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, AK 99775: Jan. 2001-present.
- "Lecturer" (Assistant Professor) in Ecology, School of Biological Sciences, Victoria University of Wellington, New Zealand: Feb. 1998-Dec. 2000.

C. Five Selected Publications:

Mulder, CPH., MN. Grant-Hoffman, D Towns, P Bellingham, M Durrett, D Wardle, and T Fukami. 2009. Direct and indirect effects of rats: will their eradication restore functioning of New Zealand seabird islands? *Biological Invasions*, 11:1671-1688

Rixen, C., and C.P.H. **Mulder**. 2009. Species removal and experimental warming in a subarctic tundra community. *Oecologia* 161: 173-186.

Mulder, CPH, B Roy, and S Güsewell. 2008. Herbivores and pathogens on *Alnus viridis* subsp. *fruticosa* in Interior Alaska: I. Effects of leaf, tree, and neighbor characteristics on damage levels. *Botany* (formerly *Canadian Journal of Botany*) 86: 408-421.

Wipf, S C Rixen, and CPH **Mulder**. 2006 Advanced snowmelt causes shift towards positive neighbour interactions in a subarctic tundra community . *Global Change Biology* 12: 1496-1506.

Mulder, CPH, DD Uliassi, and DF Doak. 2001. Physical stress and diversity-productivity relationships: the role of positive interactions. *PNAS* 98(12): 6704-6708.

D. Synergistic activities

- I am the coordinator for the Culturally Responsive Biological Science Education Project of EPSCoR III at UAF. This involves designing, coordinating, and participating in a course entitled *Alaskan Biogeography: Plants and their Symbionts* for rural secondary school teachers. The course was first run in summer 2009, and will be repeated in summer 2010.
- I will be coordinating a similar course aimed at rural secondary school teachers entitled "Pollinator Attraction: Do Exotics Do It Better?". The focus of this course will be interactions between native plants (*Vaccinium* species) and a non-native plant (*Melilotus officinalis*) via pollinators, with emphasis on the importance of flowering phenology.

BIOGRAPHICAL SKETCH

VLADIMIR EVGENI ROMANOVSKY

PROFESSIONAL PREPARATION:

M.S. - 1975; Geophysics (Honor Diploma), Moscow State University
M.S. - 1985; Mathematics (Honor Diploma), Moscow State University
Ph.D. - 1982; Geology, Moscow State University
Ph.D. - 1996; Geophysics, University of Alaska, Fairbanks

APPOINTMENTS:

Professor of Geophysics, University of Alaska Fairbanks, Alaska, 2006-present
Associate Professor of Geophysics, University of Alaska Fairbanks, Alaska, 1999-2006
Research Associate Professor, Geophysical Institute, U of Alaska Fairbanks, Alaska, 1998-1999
Research Associate, Geophysical Institute, University of Alaska Fairbanks, Alaska, 1996-1998
Research Assistant, Geophysical Institute, University of Alaska Fairbanks, Alaska, 1992-1996
Associate Professor of Geophysics and Geocryology, Moscow State University, 1985-1992
Science Researcher, Department of Geocryology, Moscow State University, Russia, 1980-1985
Geophysicist, Faculty of Geology, Moscow State University, Russia, 1975-1980

PUBLICATIONS: five most closely related to the proposed project

Brown, J. and V. E. Romanovsky, Report from the International Permafrost Association: State of Permafrost in the First Decade of the 21st Century, *Permafrost and Periglacial Processes*, 19: 255–260, 2008.

Romanovsky, V. E., Sazonova, T. S., Balobaev, V. T., Shender, N. I., and D. O. Sergueev, Past and recent changes in permafrost and air temperatures in Eastern Siberia, *Global and Planetary Change*, 56: 399-413, 2007.

Romanovsky, V.E., Gruber, S., Instanes, A., Jin, H., Marchenko, S.S., Smith, S.L., Trombotto, D., and K.M. Walter, Frozen Ground, Chapter 7, In: *Global Outlook for Ice and Snow*, Earthprint, United Nations Environment Programme/GRID, Arendal, Norway, pp. 181-200, 2007.

Sazonova, TS, Romanovsky, VE, Walsh, JE, and DO Segueev, 2004. Permafrost dynamics in 20th and 21st centuries along the East-Siberian transect, *Journal of Geophysical Research*, V. 109, DO1108.

Romanovsky, V, Burgess, M, Smith, S, Yoshikawa, K, and Brown, J, 2002. Permafrost temperature records: Indicators of climate change, *EOS*, *AGU Transactions*, *83*, 50, 589-594, December 10.

SYNERGISTIC ACTIVITIES:

1. Service to the scientific community as a President of the US Permafrost Association, 2004-2006.
2. Service to the scientific community as a member of the CliC scientific steering group (SSG), 2008-present.
3. Service to the scientific community as a member of the Executive Committee of the International Permafrost Association (IPA), 2008-present.
4. Service to the Alaskan community as a member of the Technical Working Group on Public Infrastructure (Adaptation), Alaska Governor's Climate Change Sub-Cabinet, 2008 – present
5. Service to the scientific community as a member of the US Polar Research Board, 2008-present.

COLLABORATORS OTHER AFFILIATIONS:

Collaborators: Prof. L.D. Hinzman, N. Molders, D. Nicolsky (U of Alaska), Dr. J. Brown (IPA)

T. SCOTT RUPP

Professional Preparation:
Postdoctoral Fellow in Ecological Modeling, University of Minnesota, 1997-2000
Ph.D. in Forest Ecology, University of Alaska, 1998
B.S. in Forest Science, Pennsylvania State University, 1993

Appointments:

2007-present	Director, Scenarios Network for Alaska Planning, University of Alaska Statewide
2006-present	Associate Professor, Forest Sciences Department, University of Alaska Fairbanks
2001-2006	Assistant Professor, Forest Sciences Department, University of Alaska Fairbanks
2000-2001	Research Assistant Professor, Forest Sciences Dept., Univ. of Alaska Fairbanks

Five Most-Relevant Publications (of ~ 40):
Brubaker, L.B., P.E. Higuera, T.S. Rupp, M. Olson, P.M. Anderson, and F.S. Hu. 2009. Linking sediment charcoal records and ecological modeling to understand causes of fire-regime change in boreal forests. Ecology. 90:1788-1801.
Rupp, T.S., X. Chen, and A.D. McGuire. 2007. Sensitivity of simulated boreal fire dynamics to uncertainties in climate drivers. Earth Interactions. 11:1-21.
Duffy, P.A., J. Epting, J.M. Graham, T.S. Rupp, and A.D. McGuire. 2007. Analysis of Alaskan burn severity patterns using remotely sensed data. International Journal of Wildland Fire. 16:277-284.
Rupp, T.S., Olson, M., Henkelman, J., Adams, L., Dale, B., Joly, K., Collins, W., and A.M. Starfield. 2006. Simulating the influence of a changing fire regime on caribou winter foraging habitat. Ecological Applications 16:1730-1743.
Duffy, P.A., J.E. Walsh, J.M. Graham, D.H. Mann, and T.S. Rupp. 2005. Impacts of the east Pacific teleconnection on Alaskan fire climate. Ecological Applications. 15(4):1317-1330.

Synergistic Activities:
- Co-chair, Sixth International Conference on Disturbance Dynamics in Boreal Forests
- Treasurer, International Boreal Forest Research Association 12th International Conference
- Working Group Member, Global Change and Terrestrial Ecosystems (GCTE) Task 2.2.2 - Global Change Impacts on Landscape Fires
- Working Group Member, Study of Environmental Arctic Change (SEARCH) - Biocomplexity Incubation Activity
- Working Group Member, Arctic Research Consortium of the United States (ARCUS) - Arctic Geographical Information Systems (GIS) Workshop
- Faculty Member, Interdisciplinary Graduate Education and Research Training (IGERT) program in Resilience and Adaptation

Thesis advisor: J. Yarie
Postdoctoral advisors: A.M. Starfield and F.S. Chapin, III

Current PhD advisees: K. Joly
Current MS advisees: M. Richmond

Past Graduate Students: D. Cheyette (MS 2004), T. Kurkowski (MS 2005), P. Duffy (PhD 2006)

EDWARD ARTHUR GEORGE SCHUUR
Associate Professor of Ecosystem Ecology; Department of Biology, University of Florida
220 Bartram Hall, Gainesville, FL 32611; Phone: 352-392-7913; Fax 352-392-3993; Email: tschuur@ufl.edu

Education
University of Michigan, Cellular and Molecular Biology, B.S., *magna cum laude*, (1991)
University of California/Berkeley, Soil Science/Ecosystem Ecology, Ph.D., (1999)
University of California/Irvine, Bioinformatics/Isotopes, Postdoc Fellow (1999-2002)

Appointments
Associate Professor, Department of Biology, University of Florida (2008-present)
Assistant Professor, Department of Botany, University of Florida (2002-2008)
Affiliate Professor, Soil & Water Science Dep't, University of Florida (2003-)
Courtesy Professor, Dep't of Arctic Biology, University of Alaska (2004-)

Related Publications (out of 46 published or submitted peer reviewed papers)
Schuur, E.A.G.*, J.G. Vogel*, K.G. Crummer, H. Lee, J. O. Sickman, and T.E. Osterkamp. 2009. The effect of permafrost thaw on old carbon loss and net carbon exchange in upland tundra. Nature 459:556-559.
Schuur, E.A.G., J. Bockheim, J. Canadell, E. Euskirchen, C.B. Field, S.V Goryachkin, S. Hagemann, P. Kuhry, P. Lafleur, H. Lee, G. Mazhitova, F. E. Nelson, A. Rinke, V. Romanovsky, N. Shiklomanov, C. Tarnocai, S. Venevsky, J. G. Vogel, S.A. Zimov. 2008. Vulnerability of permafrost carbon to climate change: Implications for the global carbon cycle. BioScience 58: 701-714.
Zimov, S.A., **E.A.G. Schuur**, and F.S. Chapin III. 2006. Permafrost in the global carbon budget. Science 312:1612-1613.
Randerson, J.T., S.D. Chambers, F.S. Chapin III, M.G. Flanner, M.L. Goulden, J.W. Harden, P.G. Hess, Y. Jin, H. Liu, M.C. Mack, J.C. Neff, G. Pfister, **E.A.G. Schuur**, K.K. Treseder, L.R. Welp, and C.S. Zender. 2006. The impact of boreal forest fires on climate. Science 314:1130-1132.
Mack, M.C.*, **E.A.G. Schuur*,** M.S. Bret-Harte, G.R. Shaver, and F.S. Chapin III. 2004. Ecosystem carbon storage in arctic tundra reduced by long-term nutrient fertilization. Nature 431: 440-443.

Synergistic Activities
Development and teaching of a short course to expand the understanding and use of radiocarbon measurements. Radiocarbon in Ecology and Earth Science, taught at University of California, Irvine, 2004-2009, in collaboration with Dr. Susan Trumbore.
Public outreach. Radio Interview for The Weather Notebook, Global Climate Change segment. Interviews for Reuters, the Los Angeles Times, the San Francisco Chronicle, Science News, Popular Science, Discover Magazine, Newsweek, and many others.
Grant and paper reviewer for multiple federal agencies and journals.
Member of the NCEAS Working Group on the Vulnerability of Carbon in Permafrost: Pool size and Potential Effects on the Climate System, March & December 2006.
Review panel member. Environmental Protection Agency, Science to Achieve Results (STAR) program. March, 2005, Washington DC.
All-scientists community review panel. NSF, NASA, USDA North American Carbon Program (NACP). May, 2003, Washington DC.
Involved undergraduates with field and lab research. Over the past 8 years, 30+ undergraduates gained experience in research working with my lab group.

Elena Bautista Sparrow

Professional Preparation

University of the Philippines	Soil Science, B.S. Agriculture, *cum laude*	1962
Cornell University	Soil Microbiology, Agronomy M.S.	1966
Colorado State University	Soil Microbiology, Agronomy Ph. D.	1973

Certified Professional Soil Scientist, American Registry of Certified Professionals in Agronomy, Crops and Soils, 1981 to present; Certified Science Education Trainer for Trainers, Global Learning and Observations to Benefit the Environment (GLOBE) 1966 to present, and Microcosmos Science Education Program since 1993.

Appointments- recent

2008-present	Research Professor of Soil Microbiology & Environmental Science, School of Natural Resources and Agricultural Sciences (SNRAS), University of Alaska Fairbanks (UAF)
2005-present	Director of Education and Outreach, International Arctic Research Center
2007-2009	Director, University of the Arctic International Polar Year (IPY) Higher Education Outreach Office, UAF
2000-2008	Research Assoc. Prof. of Soil Microbiology & Envir. Science, SNRAS, UAF
1985-2000	Affiliate Associate Professor of Environmental Microbiology and Science Education, School of Agriculture & Land Resources Management (SALRM), UAF
1992-1995	Microbiologist GS-12 U.S.D.A. Agricultural Research Service, Fairbanks, AK

Publications *Five most relevant*

Gazal, R., White, M., Gillies, R., Rodemaker, E., Sparrow, E. and Gordon, L. 2008. GLOBE students, teachers, and scientists demonstrate variable differences between urban and rural leaf phenology along a multi-continent bioclimatic gradient. *Global Change Biology*, 14, 1-13, doi:10.1111/j.1365-2486.2008.01602.x.

Robin, J.H., Dubaya, R., Sparrow, E., and Levine, E. 2007. Monitoring start of season in Alaska with GLOBE, AVHRR and MODIS data. *Journal of Geophysical Research – Biogeosciences*. 113, G01017, doi:10.1029/2007JG000407.

Sparrow, E.B., Dawe, J. and Chapin F.S.III. 2006. Communication of Boreal Science with Broader Communities, Pages 465- 479 in Chapin, F. S., III, M. Oswood, K. Van Cleve, L. Viereck, and D. Verbyla, eds. *Alaska's Changing Boreal Forest*. Oxford University Press, Oxford, In press.

Gordon, L., Stephens, S. and Sparrow, E. B. 2005. Applying the National Science Education Standards in Alaska: Weaving Native Knowledge into Teaching and Learning Environmental Science Through Inquiry, Pp. 85-98 in Yager, R.E. ed. *Exemplary Science: Best Practices in Professional Development*. NSTA Press, Arlington, VA.

Penuel, W.R., Shear, L., Korbak, C., Sparrow, E. B. 2005. The roles of Regional Partners in Supporting an International Earth Science Education Program. *Science Education* 89 (6): 85-98 Wiley Periodicals Inc. New Jersey.

Synergistic Activities

Member: Review Panel on the International Council for Science(ICSU)'s role in science education; IPY International Education Outreach & Communications Committee; UAF Center for Global Change Science Steering Committee; PI, NSF Monitoring Seasons Through Global learning Communities; Co-PI, NSF Collaborative Research- Spatial and Temporal Influences of Thermokarst Features on Surface Processes in Arctic Landscapes.

Biographical Sketch: Donald Lee Taylor

Institute of Arctic Biology
PO Box 757000
University of Alaska Fairbanks
Fairbanks, AK 99775-7000

(i) PROFESSIONAL PREPARATION

Yale University, New Haven, CT	Biology	B.S. 1989
University of Florida, Gainesville, FL	Agronomy	B.S. 1990
University of California, Berkeley, CA	Plant and Microbial Biology	Ph.D. 1997
University of California, Santa Barbara, CA	Speciation	Postdoc, 1997-1999
University of California, Santa Barbara, CA	Population genetics	Postdoc, 1999
University of California, Berkeley, CA	Plant evolutonary ecology	Postdoc, 1999-2002

(ii) APPOINTMENTS

Assistant Professor, Institute of Arctic Biology and Department of Biology and Wildlife, University of Alaska, Fairbanks, 2002 - 2008;
Associate Professor, Institute of Arctic Biology and Department of Biology and Wildlife, University of Alaska, Fairbanks, 2008 - present

(iii) FIVE MOST CLOSELY RELATED PUBLICATIONS

Taylor DL, Herriott IC, Stone KE, McFarland JW, Booth MG, Leigh MB. Structure and resilience of fungal communities in Alaskan boreal forest soils. ***Canadian Journal of Forest Research***. *In Press*.
Larsen T, **Taylor DL**, Leigh MB, O'Brien DM. 2009. Stable isotope fingerprinting: a novel method for identifying plant, fungal, or bacterial origins of amino acids. ***Ecology*** 90 (12): 3526-3535.
Anderson MD, Ruess RR, Myrold DD, **Taylor DL**. 2009. Host species and habitat affect nodulation by specific *Frankia* genotypes in two species of *Alnus* in interior Alaska. ***Oecologia*** 160 (4): 619-630.
Taylor DL, Booth MG, McFarland JW, Herriott IC, Lennon NJ, Nusbaum C & Marr TG. 2008. Increasing ecological inference from high throughput sequencing of fungi in the environment through a tagging approach. ***Molecular Ecology Resources*** 8(4): 742 - 752.
Taylor DL, Herriott IC, Long J and O'Neill K. 2007. TOPO TA is A-OK: a test of phylogenetic bias in fungal environmental clone library construction. ***Environmental Microbiology*** 9: 1329-1334.

(iv) SYNERGISTIC ACTIVITIES

1) Development of publicly accessible bioinformatic tools for sequence-based fungal identification; see http://www.borealfungi.uaf.edu/
2) Manuscript reviews for numerous journals including American Naturalist, BMC Evolutionary Biology, Ecology, Environmental Microbiology, Evolution, FEMS Microbiology Ecology, Molecular Ecology, Proceedings of the Royal Society of London, PNAS and Science.
3) Service on four NSF panels spanning MCB Microbial Observatories, MCB Microbial Interactions and Processes, NSF DEB Evolutionary Genetics and NSF DEB Biophylogeography, plus numerous ad hoc reviews.
4) Councilor in Ecology for the Mycological Society of America 2008-2010 and host for the MSA annual meeting in 2011.

Merritt Rae Turetsky
Assistant Professor
Department of Integrative Biology
University of Guelph

Professional Preparation:

1997	B.Sc. Biology, Department of Biology, Villanova University, U.S.A.
2002	Ph.D. Ecology and Environmental Biology, University of Alberta, Canada
1998-2000	Graduate Research Fellow, Dept. Biological Sciences, University of Alberta
2001-2002	Killam Doctoral Fellow, University of Alberta
2002	Visiting Scientist, Climate Change Group, Canadian Forest Service
2002-2004	Mendenhall Postdoctoral Research Fellow, U.S. Geological Survey

Appointments:

2008-current	Assistant Professor, Univ of Guelph
2008-current	Senior Research Associate, Institute of Arctic Biology, Univ of Alaska-Fairbanks
2004-2008	Assistant Professor of Wetland Ecology, Michigan State Univ

Synergistic Activities:

co-Principal Investigator and member of steering committee of PeatNet: An international research framework for globalization of peatland ecology, NSF RCN

Organizing committee Biogeomon, 4th Conference on Ecosystem Behaviour, June 2006

Manuscript reviews for refereed journals in recent years: *Applied Geochemistry*, *Canadian Journal of Forest Research, Canadian Journal of Soil Science, Ecosystems, Ecoscience, Ecological Modeling, Global Change Biology, Forest Science, Journal of Geophysical Research, PNAS, Water Air and Soil Pollution, Wetlands*

Assistant editor for *Ecosystems*

Proposal reviews for funding agencies in recent years: *NSF (Ecosystems), NASA Young Investigators Award and research proposals, Fluxnet Canada 3 year review and Add on Proposals (10 million dollar proposal), EPA STAR Graduate Research panel 2005, 2006*

Relevant Publications:

Dr. Turetsky has authored or co-authored 40 articles in refereed journals and 5 book chapters since 2000. Her 5 most relevant publications are:

1) Shetler, G., M.R. Turetsky, E. Kane, E.S. Kasischke. 2008. *Sphagnum* mosses limit total carbon consumption during fire in Alaskan black spruce forests. Canadian Journal of Forest Research 38: 2328-2336
2) Turetsky, M.R., C.C. Treat, M. Waldrop, J.M. Waddington, J.W. Harden, A.D. McGuire. 2008. Short-term response of methane fluxes and methanogen activity to water table and soil warming manipulations in an Alaskan peatland. Journal of Geophysical Research Biogeosciences, 113, doi: 10.1029/2007JG00496
3) Turetsky, M.R., S.E. Crow, R.J. Evans, D.H. Vitt, R.K. Wieder. 2008. Tradeoffs in resource allocation among moss species control decomposition in boreal peatlands. Journal of Ecology 96: 1297-1305
4) Turetsky, M.R., R.K. Wieder, D.H. Vitt, K. Scott. 2007. The disappearance of relict permafrost n boreal regions: effects on peatland carbon storage and fluxes. Global Change Biology 13: 1-13
5) Turetsky, M.R., J.W. Harden, H. Friedli, M. Flannigan., N. Payne, J. Crock, L. Radke. 2006. Wildfires threaten mercury stocks in northern soils. Geophysical Research Letters, 33, 10.1029/2005GL025595.

DAVID W. VALENTINE · dvalentine@alaska.edu · (907) 474-7614
Dept. of Forest Sciences, University of Alaska, Fairbanks, AK 99775-7200

(a) Professional Preparation

Wittenberg University	Biology	BA 1981
Duke University	Forest Ecology	MS 1984
Duke University	Ecosystem Ecology	PhD 1990
Colorado State University	Ecosystem Ecology	Postdoctoral 1989-1993

(b) Professional Appointments

Associate Professor of Forest Soils	University of Alaska	2003-present
Assistant Professor of Forest Soils	University of Alaska	1996-2003
Research Associate	Colorado State University	1993-1996

(c) 5 Relevant Publications

Kane, E.S., **D.W. Valentine**, G.J. Michaelson, J.D. Fox, and C.-L. Ping. 2006. Controls over pathways of carbon efflux from soils along climate and black spruce productivity gradients in interior Alaska. Soil Biology & Biochemistry 38:1438-1450.

Kane, E.S., **D.W. Valentine**, E.A.G. Schuur, and K. Dutta. 2005. Soil carbon stabilization along climate and stand productivity gradients in black spruce forests of interior Alaska. Canadian Journal of Forest Research 38(6):1438-1450.

Valentine, D.W., K. Kielland, F.S. Chapin, III, A.D. McGuire, and K. Van Cleve. 2006. Patterns of Biogeochemistry in Alaskan Boreal Forests. Chapter 15 in "Alaska's Changing Boreal Forest", Chapin, F.S. III, M. Oswood, K. Van Cleve and D. Verbyla, Eds. Oxford University Press, Oxford, UK.

Vogel, J.G., B.P. Bond-Lamberty, E.A.G. Schuur, S.T. Gower, M.C. Mack, K.E.B. O'Connell, **D.W. Valentine**, R.W. Ruess. 2008. Carbon allocation in boreal black spruce forests across regions varying in soil temperature and precipitation. Global Change Biology 14: 1503-1516.

Vogel, J.G., **D.W. Valentine**, and R.W. Ruess. 2005. Soil and root respiration in mature Alaskan black spruce forests that vary in soil organic matter decomposition rates. Canadian Journal of Forest Research 35:161-174.

(d) Synergistic Activities

Director, Calypso Farm and Ecology Center (local non-profit advancing sustainable agricultural practices in interior Alaska through research and K-12 education): 2005-present

Instructor, UAF Resilience and Adaptation Program (NSF-funded IGERT program offering interdisciplinary graduate education in development of sustainable social ecological systems): 2001-present.

Dr. David Verbyla

Present Position and Address:
Professor of Remote Sensing/Geographic Information Systems
Department of Forest Sciences, School of Natural Resources and Agricultural Sciences
University of Alaska Fairbanks, Fairbanks, AK 99775
Phone: 907-474-5553, Fax: 907-474-6184
Email: D.Verbyla@uaf.edu Web Site: http://nrm.salrm.uaf.edu/~dverbyla

Education:
Natural Resources Management, Cook College, Rutgers University, B. S. 1979
Park and Recreation Resources, Michigan State University, M. S. 1982
Forest Resources, Utah State University, Ph. D. 1988

Current non-LTER Research Projects:

Remote Sensing of Shallow Lake Changes in Denali and Kobuk Dunes National Parks, Alaska. National Park Service, 1/2005-1-2011, $75k

Using Remote Sensing to Investigate Landscape Fire Interactions in Black Spruce Ecosystems of Interior Alaska, USDA Forest Service, 2/2005-2/2001, $225k

Five LTER funded Publications:

Verbyla, D. 2008. *The greening and browning of Alaska based on 1982-2003 satellite data.* Global Ecology and Biogeography 17:547-555.

Verbyla, D. and R. Lord. 2008. *Estimating post-fire organic soil depth in the Alaskan boreal forest using the Normalized Burn Ratio.* International Journal of Remote Sensing. 29(13):3845-3853.

Verbyla, D., Kasischke, E. S., and Hoy, E. E. 2008. Seasonal and topographic effects on estimating fire severity from Landsat TM/ETM + data. International Journal of Wildland Fire. 17:527-534

Riordan, B., Verbyla, D. and A. D. McGuire. 2006. *Shrinking ponds in subarctic Alaska based on 1950-2002 remotely sensed images.* Journal of Geophysical Research. 111,G04002, doi:10.1029/2005JG000150, 2006

Epting, J. and D. L. Verbyla. 2005. *Landscape level interactions of pre-fire vegetation, burn severity, and post-fire vegetation over a 16-year period in interior Alaska.* Canadian Journal of Forest Research. 35:1367-1377.

Diane Wagner

Institute of Arctic Biology and Department of Biology & Wildlife, University of Alaska Fairbanks

Professional Preparation

University of California Berkeley	Biology	B.S.	1986
Princeton University	Ecology & Evolution	Ph.D.	1994
Washington State University	Botany & Zoology	Post-doctoral	1994
Stanford University	Biological Sciences	Postdoctoral	1994-1998

Appointments

Associate Professor	University of Alaska Fairbanks	2007 – present
Assistant Professor	University of Alaska Fairbanks	2002 – 2007
Assistant Professor	University of Nevada Las Vegas	1998 – 2002
Postdoctoral Research Associate	Stanford University	1996 – 1998
Visiting Assistant Professor	Mills College	1996
USDA Postdoctoral Fellow	Stanford University	1994 – 1996
Postdoctoral Research Associate	Washington State University	1994

Relevant Publications

Wagner D & Nicklen EF (2010) Ant nest location, soil nutrients, and nutrient uptake by ant-associated plants: Does extrafloral nectar attract ant nests and thereby enhance plant nutrition? *Journal of Ecology*, in press.

Wagner D, DeFoliart L, Doak P, Schneiderheinze J. (2008) Impact of epidermal leaf mining by the aspen leaf miner (*Phyllocnistis populiella*) on growth, physiology, and leaf longevity of quaking aspen. *Oecologia* 157: 259-267.

Doak P, Wagner D & Watson A. (2007) Variable extrafloral nectary expression and its consequences in quaking aspen. *Canadian Journal of Botany*, 85: 1-9.

Wagner D & Jones JB (2006) The impact of harvester ant nests on decomposition, N mineralization, litter quality, and availability of N to plants in the Mojave Desert. *Soil Biology & Biochemistry* 38: 2593-2601.

Young BD, Wagner D, Clausen T & Doak P. Induction of phenolic glycosides in aspen (*Populus tremuloides*) in response to epidermal leaf mining by an outbreak insect species, *Phyllocnistis populiella*. In review, *Journal of Chemical Ecology*

Synergistic Activities

1. Conducted summer ecology internships for Native Alaskan junior high school students.
2. Contributed to the Science and Math Enrichment Program for rural Alaska Native students preparing for high school
3. Informed the public about insect ecology through Pulse of the Planet interviews
4. Consulted on Nature documentary "Metamorphoses"
5. Developed numerous field and laboratory exercises for university students of introductory biology, ecology, field ecology

Graduate and Post-Graduate Advisors

Henry S. Horn, Princeton University; Deborah M. Gordon, Stanford University; Carlos Martínez del Rio, University of Wyoming; Naomi E. Pierce, Harvard University; John N. Thompson, University of California Santa Cruz

Graduate Students and Post-Docs Supervised

E. Fleur Nicklen (MS 2006), Brian D. Young (MS 2009), Brent D. Mortensen (MS 2009), Jonathon Newman (MS in progress)

John Yarie

Education: West Virginia University, Forest Management, B. S. Forest Management, 1971
University of Maine, Forestry, M.S. Forest Ecology, 1974
University of British Columbia, Forest Ecology, Ph.D. Forest Ecology, 1978

Appointments:

Professor of Silviculture, Forest Sciences Department, 1997 - present
Associate Professor of Silviculture, Forest Sciences Department, 1991 - 1997
Assistant Professor of Silviculture, Forest Sciences Department, 1987 - 1991
Visiting Assistant Professor of Forest Ecology and Silviculture, Forest Sciences Department, 1982 - 1987
Research Associate, Forest Soils Laboratory, 1978 - 1982
All positions with School of Natural Resources and Agricultural Sciences
University of Alaska Fairbanks, Fairbanks, Alaska 99775

Research Interests: Structure and function of boreal forests, successional processes following catastrophic disturbances, effects of changing environmental conditions on forest processes, representation of current thinking on forest processes in theoretical constructs though modeling exercises.

Professional Experience: Professor of Silviculture 1997 - present, Director of the Forest Soils Laboratory 1995 - present, Associate Professor of Silviculture 1991-1997, Assistant Professor of Silviculture 1987-1991, Visiting Assistant Professor of Silviculture and Forest Ecology 1982-1987, Forest Soils Laboratory, Agriculture and Forestry Experiment Station, University of Alaska Fairbanks

Publications: (selected from 65 publications in various outlets)

Yarie, J. 2008. Effects of moisture limitation on tree growth in upland and floodplain forest ecosystems in interior Alaska. Forest Ecology and Management 256:1055-1063.

Yarie, J. and K. Van Cleve. 2006. Controls over forest production in Interior Alaska. Chapter 11. Alaska's Changing Boreal Forest. F. Stuart Chapin III, Mark W. Oswood, Keith Van Cleve, Leslie A. Viereck and David L. Verbyla (eds.). Oxford University Press. 354 pgs.

Yarie, J. and W. Parton. 2005. Potential changes in carbon dynamics due to climate change measured in the past two decades. Can. J. For. Res. 35:2258-2267.

Billings, S. S., and J. Yarie. 2000. Sensitivity of soil methane fluxes to reduced precipitation in boreal forest soils. Soil Biology and Biochemistry 32:1431-1441.

Yarie, J. and K. Van Cleve. 1996. Effects of carbon, fertilizer and drought on foliar nutrient concentrations of taiga tree species in interior Alaska. Ecological Applications. 6:815-827.

Synergistic Activities:

I teach the Forest Ecology and Silviculture classes in the Forestry Curriculum. I am always updating examples used in class for boreal ecosystems based on the knowledge gained from the research conducted at field sites in interior Alaska. I have developed a modeling structure that used the nitrogen productivity concept as the major driving variable controlling forest growth. In addition I have utilized the CENTURY, LINKAGES and FORCYTE models for additional analysis. Work is also in progress in calibrating the DAYCENT model for interior Alaskan forest types.

Table 7. Annual allocation of LTER funds (direct costs) among projects ($/yr). Values change slightly from year to year. Data are shown for year 6.

		NSF	Forest Service	Total
Core Research				**521,317**
	Data Management	126,437	0	126,437
	Site Management	150,880	182,000	332,880
	Watershed Studies	42,000	0	42,000
	Forest Soils Laboratory	20,000	0	20,000
Individual Projects				**434,233 (d)**
	Euskirchen	10,000	0	10,000
	Hanley	0 (a)	0	0
	Harden	10,000	0	10,000
	Teresa Hollingsworth	26,000 (a)	0	26,000 (a)
	Johnstone	25,733	0	25,733
	Jones	25,000	0	25,000
	Juday	8,700	0	8,700
	Kasischke	4,800	0	4,800
	Kielland	43,500 (b)	0	43,500 (b)
	Kofinas	20,000	0	20,000
	Leigh	0 (c)	0	0
	Lloyd	20,000	0	20,000
	Mack	25,000	0	25,000
	McGuire	26,200	0	26,200
	Mulder	15,000	0	15,000
	Romanovsky	8,700	0	8,700
	Ruess	27,000 (b)	0	27,000 (b)
	Rupp	18,300	0	18,300
	Schuur	25,000	0	25,000
	Sparrow	0 (c)	0	0
	Taylor	18,300	0	18,300
	Turetsky	10,000	0	10,000
	Valentine	8,700	0	8,700
	Verbyla	25,000	0	25,000
	Wagner	15,000	0	15,000
	Yarie	18,300	0	18,300
Total Direct Costs		**662,420**	**182,000**	**844,420**
Indirect Costs (35%)		**231,847**	**0**	
Total Project Budget		**940,000**	**182,000**	**1,187,397 (d)**

(a) Salary for Hanley and Hollingsworth come directly from the Forest Service
(b) Project funds for Ruess and Kielland are provide by UAF's Institute of Arctic Biology (IAB), constituting IAB's direct financial support for the BNZ LTER program
(c) Programs of Sparrow (K-12 Education) and Leigh (Arts/humanities outreach) are supported through the BNZ LTER Supplement Program.
(d) Includes IAB commitment of $70k/yr

Table 8. Related research funded by BNZ LTER senior investigators over the review period (only includes 2005-2010) totals $38.71 million.

PI	Project title	Funging Agency	Date	YRS	Total Budget	Annual Budget
Chapin	Arctic System Science, Land-Atmosphere-Ice Interactions, Science Management Office.	NSF	2001	5	820,493	164,099
Chapin	Regional Resilience and Adaptation: Planning for Change	NSF	2001	7	3,231,538	461,648
Chapin	Continuation of Bonanza Creek LTER Program	USFS	2001	6	1,088,226	181,371
Chapin	Methan efflux from thermokarst lakes in NE Siberia: Physical, hydrological, and biogeochemical controls.	NASA	2002	3	71,978	23,993
Chapin	Fire-Mediated Changes in the Arctic System: Interactions of Changing Climate and Human Activities	NSF	2003	4	1,347,857	336,964
Chapin	Wildfire effects on subsistence resources in rural Alaska: Integration of western and traditional knowledge	Murdock Trust	2005	3	14,000	4,667
Chapin	Dynamics of Change in ALaska's Boreal Forests (A Continuation of the Bonanza Creek Long-Term Ecological Research Program)	USFS	2006	5	950,090	190,018
Chapin	IPY: Impacts of High-Latitude Climate change on Ecosystem Services and Society	NSF	2007	3	2,142,115	714,038
Chapin	Community Adaptation to Climate Change in Interior Alaska: A Workshop to Develop Adaptation Options and Sustain Ecosystem Services	The Christensen Fund	2007	1	10,000	10,000
Grosse	Assessing the spatial and temporal dynamics of thermokarst and related carbon cycling in Siberia and Alaska	NASA	2008	3	676,307	225,436
Harden	Fate of Carbon on Alaskan Landscapes	USGS	2005	5	2,500,000	500,000
Harden	Impact of Permafrost Degradation on Carbon and Water in Boreal Ecosystems	NSF	2007	4	2,000,000	500,000
Harden	NSF Critical Zone Observatories: Instrumentation for Bonanza Wetland Gradient	NSF	2007	1	10,000	10,000
Hinzman	Climate changes over E. Siberia	NASA	2006	4	600,000	150,000
Hollingsworth	Predicting ecosystem trajectories in burned black spruce forests in Alaska	USFS	2006	2	452,460	226,230
Hollingsworth	Collaborative Research on response of terrestrial ecosystems and permafrost to climate change in the Yukon River Basin	USGS	2009	1	21,467	21,467
Johnstone	Fire as a catalyst of boreal forest responses to climate change	NSERC	2007	5	125,000	25,000
Johnstone	Past processes, past changes, and spatiotemporal variability in the Arctic delimitation zone, Canada	Canada IPY Program	2007	5	114,000	22,800
Jones	Noatak Thermokarst Assessment 2006	NPS	2006	2	65,874	32,937
Jones	Collaborative Research: Spatial and Temporal Influences of Thermokarst Features on Surface Processes in Arctic Landscapes	NSF	2008	4	1,444,296	361,074

Juday	Spruce Budworm	USFS	2007	1	6,000	6,000
Kasischke	Burning of Organic Soils in Boreal Forests	NASA	2004	4	750,000	187,500
Kasischke	Remote Monitoring of Changes in Forest Functional Types after Disturbance from Fire in the North American Boreal Region: Implications for Interpreting the Effects of Satellite-Observed Changes in Vegetation Greenness of the Terrestrial Carbon Budget	NASA	2006	4	768,000	192,000
Kasischke	Assessing the Impacts of Fire and Insect Disturbance on the Terrestrial Carbon Budgets of Forested Areas in Canada, Alaska, and the Western United States	NASA	2008	3	569,000	189,667
Kasischke	Vulnerability and Resiliency of Arctic and Sub-Arctic Landscapes (VuRSAL) - the Role of Interactions between Climate, Permafrost, Hydrology, and Disturbance in Driving Ecosystem Processes	NASA	2009	1	229,000	229,000
Kielland	Controls over White Spruce Establishment in Floodplain Plant Communities	USFS	2001	5	55,000	11,000
Kielland	Feedbacks between river hydrology and terrestrial nitrogen dynamics in taiga forests	Mellon	2002	3	270,608	90,203
Kielland	Primary Succession of Yukon River Floodplains	USFS	2007	5	75,000	15,000
Kielland	Dangerous Ice: Human perspectives on changing winter conditions in Alaska	NSF	2009	3	359,658	119,886
Kofinas	Resilience of Human-Rangifer Systems	NSF	2005	5	750,296	150,059
Kofinas	OPUS: Resilience and Adaption	NSF	2007	3	144,978	48,326
Kofinas	IGERT: Global-Local Interactions	NSF	2007	3	3,187,173	1,062,391
Kofinas	Synthesis and analysis of Community Based Ecological Monitoring Data	Arctic Borderlands Ecol. Knowledge Coop	2009	1	20,305	20,305
Kofinas	Modeling Subsistence Behavior in the Context of a Northern Social-ecological System to Understand Trade-Offs	NSF	2009	3	316,779	105,593
Laursen	Assessment of Wetlands	CRREL	2008	2	143,330	71,665
Lloyd	Collaborative Research/RUI: Past, Present and Future Productivity of Arctic Woody Vegetation in a Warming Climate	NSF	2006	4	167,386	41,847
Lloyd	Timing of Warm-Season Precipitation: Key Mediator Between Climate Change and the Boreal Forest?	NSF	2009	3	143,937	47,979
Mack	Collaborative Research: Spatial and Temporal Influences of Thermokarst Features on Surface Processes in Arctic Landscapes	NSF	2008	4	800,000	200,000
Mack	Quantifying changes in norther high latitude ecosystems and associated feedbacks to the climate system	NASA	2008	3	280,000	93,333
Mack	Collaborative research on shrub-snow interactions in Alaskan and Canadian tundra and their potential for positive feedback to vegetation and climate change	NSF	2005	4	270,000	67,500

Mack	Fighting fire with fire: predicting and manipulating the trajectory of vegetation recovery following fire in boreal forest	JFSP	2005	3	180,000	60,000
Mack	Controls over fungal communities and consequences for nutrient cycling	NSF	2005	4	150,000	37,500
Mack	Climate change and wildfire in the far north	NCEAS	2009	1	65,500	65,500
Mann	Timing of Warm-Season Precipitation: Key Mediator Between Climate Change and the Boreal Forest?	NSF	2009	3	797,130	265,710
McGuire	Fate of carbon in Alaska landscapes	USGS	2000	5	132,821	26,564
McGuire	Collaborative Research. Modeling the Role of High Latitude Terrestrial Ecosystems in the Arctic System: A Retrospective Analysis of Alaska as a Regional System.	NSF	2001	4	314,979	78,745
McGuire	Carbon responses along moisture gradients in Alaska landscapes	USGS	2005	5	163,679	32,736
McGuire	Soil climate and its control on wetland carbon balance in interior Alaska – Experimental manipulation of thermal and moisture regimes	NSF	2004	2	175,000	87,500
McGuire	Collaborative Research:Soil Climate and its control on wetland carbon balance in interior boreal Alaska:Experimental Manipulation	NSF	2007	5	285,000	57,000
McGuire	The role of land-cover change in high latitude ecosystems: Implications for carbon budgets of North America	NASA	2001	4	520,840	130,210
McGuire	Circumpolar Synthesis and Integration	NSF	2008	2	424,230	212,115
McGuire	Collaborative Research. Synthesis of Arctic System Carbon Cycle Research Through Model-Data Fusion Studies Using Atmospheric Inverse and Process-Based Approaches	NSF	2005	4	299,148	74,787
McGuire	Climate of the Arctic: Modeling and Processes (CAMP)		2004	4	1,022,805	255,701
McGuire	Biocomplexity – Feedbacks between ecosystems and the climate system	NSF	2001	6	259,800	43,300
McGuire	Wildfire consumption of ground-layer organic matter in North American Boreal Forests and Peatlands: Implications for atmospheric trace gas emissions and long-term soil carbon storage	NASA	2005	4	69,112	17,278
McGuire	Assessing Impact of Fire and Insect Disturbance on the Terrestrial Carbon Budgets of Forested Areas in Canada, Alaska, and Western US	CSRS	2008	3	254,000	84,667
McGuire	Assessing the Role of Deep Soil Organic Carbon in Interior Alaska: Data, Models, and Spatial/Temporal Dynamics	USGS	2008	3	246,128	82,043
McGuire	Partitioning Soil Respiration along Moisture Gradients in Alaskan Landscapes	USGS	2009	1	49,870	49,870
Mulder	Will global warming alter plant parasite loads in the boreal forest understory?	Univ Oregon	2003	2	56,403	28,202
Mulder	Assessing wildfire burn susceptibility to invasive plant colonization in black spruce forests in interior Alaska	Montana St U	2006	1	5,000	5,000

Mulder	How will water stress host susceptibility and host physiology of alder?	USFS	2007	2	1,560	780
Mulder	Are alaskan pollinators abandoning native berries for an exotic clover? Implications for invasive plant management on fruit production	USDA	2010	4	493,000	123,250
Romanovsky	Establishing Permafroast Observatory at the HAARP Site	Office of the Chief of Naval Research	2003	4	224,858	56,215
Romanovsky	Permafrost Models Comparison	Univ Deleware	2004	4	153,191	38,298
Romanovsky	Microbial Observatory: Metabolic Activity of Microorganisms in Alaskan Tundra and Permafrost	Stevens Institute of Technology	2004	2	53,407	26,704
Romanovsky	Recent and Future permafrost variability, retreat, and degradation in Greenland and Alaska	NSF	2006	4	914,697	228,674
Romanovsky	Thermal State of Permafrost (TSP): The U.S. Arctic Contribution to the International Permafrost Observatory Network	NSF	2009	3	375,021	125,007
Romanovsky	IPY: Development of a Network of Permafrost Observatories in North America and Russia: the U.S. Contribution to the International Polar Year (IPY)	NSF	2007	4	945,276	236,319
Romanovsky	Long-term Permafrost Dynamics of the Kiniktuuraq proposed relocation site for tthe community of Kivalina, AK.	Federal Highway Administration	2008	1	11,035	11,035
Romanovsky	AON: Thermal State of Permafrost (TSP) in North America and Northern Eurasia: The US Contribution to the International Network of Permafrost Observatories (INPO)	NSF	2009	5	1,859,861	371,972
Ruess	Impacts of alder dieback and mortality on ecosystem nitrogen balance in Alaska	USFS	2005	1	10,000	10,000
Ruess	Ecosystem-level Consequesnces of Mutualist Partner Choice in Alder across a Forest Successional Sequence in Interior Alaska	NSF	2007	3	810,227	270,076
Rupp	Collaborative Research: An Integrated Approach to Understanding the Role of Climate-Vegetation-Fire Interactions in Boreal Forests Responses to Climatic Change	NSF	2001	5	159,207	31,841
Rupp	Assessing the vulnerability of human populations to wildfire in the Lake states	USFS	2001	4	101,000	25,250
Rupp	Managing small diameter forest stands in interior Alaska: an analysis of the fiber supply generated through multiple natural resource objectives.	USDA	2002	2	85,000	42,500
Rupp	Classification and Modeling for FRCC Implementation in Alaska.	USFS	2006	1	32,000	32,000
Rupp	Understanding fire severity patterns in Alaska's boreal forest	Murdock	2007	1	48,000	48,000
Rupp	Development of Computer Model for Management of Fuels, Human-Fire Interactions, and Wildland Fires in the Boreal Forest of Alaska	JFSP	2007	3	411,221	137,074

Rupp	Quantifying the Effects of Fuels Reduction Treatments ono fire Behavior and Post-fire Vegetation Dynamics	JFSP	2008	4	263,789	65,947
Rupp	Modeling Fire Regimes, CESU	NPS	2008	2	16,672	8,336
Rupp	PNW Scenarios Network for Alaska Planning	USFS	2008	4	14,825	3,706
Rupp	Connecting Landscapes into the Future: A collaborative sstrategic habitat conservation project	USFWS	2009	2	99,998	49,999
Rupp	Changing Climate and Habitats on DOI Lands in Alaska	USGS	2008	1	25,000	25,000
Rupp	Climate change scenarios for NW Canada	The Nature Conservancy	2008	1	38,576	38,576
Rupp	Projected Vegetation and Fire Regime Response to Future Climate Change in Eastern Interior Alaska	BLM	2009	1	20,162	20,162
Rupp	Assessing the Impact of Climate Change in Alaska: Current Trends and Future Projections for Forests	USFS	2009	1	80,000	80,000
Schuur	The Effect of Moisture and Temperature Manipulation on Plant Allocation and Soil Carbon Dynamics in Black Spruce Forests: Using Radiocarbon to Detect Multiple Climate Change Impacts on Boreal Ecosystem Carbon Cycling	DOE NICCR	2006	3	$375,000	125,000
Schuur	REU Supplement: “The Carbon Balance of Arctic Tundra in Response to Permafrost Thawing: Using Radiocarbon to Detect the Loss of Old Carbon	NSF	2006	1	$6,000	6,000
Schuur	REU Supplement: “The Carbon Balance of Arctic Tundra in Response to Permafrost Thawing: Using Radiocarbon to Detect the Loss of Old Carbon	NSF	2007	1	$6,000	6,000
Schuur	Implementing of CAKN Permafrost and Carbon Cycling Monitoring Protocol: Development and Validation of Standard Operating Procedures	USDI	2007	3	$70,500	23,500
Schuur	CAREER: Experimental Warming, Permafrost Thawing, and the Loss of Old Carbon from Tundra: Radiocarbon Research and Education to Understand Ecosystem Feedbacks to Climate Change	NSF	2008	5	$600,000	120,000
Schuur	REU Supplement: “The Carbon Balance of Arctic Tundra in Response to Permafrost Thawing: Using Radiocarbon to Detect the Loss of Old Carbon	NSF	2008	1	$7,000	7,000
Schuur	Collaborative Research: Spatial and Temporal Influences of Thermokarst Failures on Arctic Surface Processes	NSF	2008	4	$713,166	178,292
Schuur	Development of Monitoring Techniques to Detect Change in Carbon Cycling in Relation to Thermokarst in National Parks and Preserves	USDI	2008	1	$15,000	15,000

Schuur	Permafrost Carbon in a Warming World: A Dual Isotope Approach for Partitioning Ecosystem Respiration	NOE	2009	2	$250,000	125,000
Schuur	Dissertation Improvement Grant: Tracking Ecosystem Nitrogen Cycling in Black Spruce Forests Using Novel 15N Measurements	NSF	2009	2	$14,836	7,418
Schuur	The Carbon Balance of Arctic Tundra in Response to Permafrost Thawing: Using Radiocarbon to Detect the Loss of Old Carbon	NSF	2005	9	$550,000	61,111
Schuur	Permafrost and the Global Carbon Cycle: A Research and Education Synthesis Towards Understanding Terrestrial Feedbacks to Climate Change	NCEAS	2009	1	$69,411	69,411
Sparrow	Global Change education using western science and native observations	NSF	2000	5	967,901	193,580
Sparrow	Improving Understanding of Global climate Variability	AKDNR	2001	4	220,567	55,142
Sparrow	Integrated Phenology Research and Education	Utah State Univ	2002	5	64,645	12,929
Sparrow	Monitoring Seasons Through Global Learning Communities	NSF	2006	4	1,320,458	330,115
Sparrow	Track 1 GK-12 Teaching Assistants Sharing Knowledge (TASK) in Alaska	NSF	2005	4	$1,883,820	470,955
Sparrow	Ice e-Mysteries Polar e-Book	NSF	2008	2	49,939	24,970
Taylor, Lee	Collaborative Research: Orchid-mycorrhizae interactions- a system for understanding the ecological role, distribution, and significance	NSF	2003	3	99,999	33,333
Taylor, Lee	Coupling Diversity with Function:Metagenomics of Boreal Forest	NSF	2003	4	911,591	227,898
Taylor, Lee	Collaborative Research: Relationships among gene lineages, morphology, geography and fungal associations in Corallorhizinae	NSF	2004	4	145,215	36,304
Taylor, Lee	IPY: A Community Genomics Investigation of Fungal Adaption to Cold	NSF	2007	3	743,697	247,899
Turetsky	Collaborative Research:Soil Climate and its control on wetland carbon balance in interior boreal Alaska:Experimental Manipulation	NSF	2007	5	445,000	89,000
Werner	C3: Monitor Bark Beetle Populations	USFS	2006	2	35,000	17,500
Werner	T3: Monitor Insect Defoliator Populations	USFS	2008	2	15,000	7,500
Yarie	The Dynamics of Forest Growth in Interior Alaska as Influenced by Climate Change, Nutrients and Potential Climate Warming	McIntyre-Stennis	2006	5	525,000	105,000
Yoshikawa	Current climate changes over Eastern Siberia and Interior Alaska and their impact on permafrost landscapes, ecosystem dynamics, and hydrological regime	NSF	2008	2	592,109	296,055

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory: University of Alaska Fairbanks: The Forest Soils Laboratory and the laboratories of all BNZ investigators are available to support the LTER program. These laboratories have capabilities of water, soil, and plant chemical analysis, stable isotope analyses, pollen analysis,

Clinical:

Animal:

Computer: In addition to the computer facilities used for data management and archival, which are described in section 4 of the proposal, we have additional computer resources for spatial analysis and modeling. These resources include a modern spatial ecology laboratory, which contains

Office: We can provide temporary office and laboratory space for LTER affiliates and other scientists that collaborate with LTER Researchers.

Other: Two major field sites: Research is conducted at two major field sites (Bonanza Creek Experimental Forest and Caribou-Poker Creek Research Watersheds). At both sites there long-term study plots, field experiments, and climate stations, as described in the proposal and at http://www.lter.uaf.edu/About_us.cfm. In addition, the University of

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

Laboratory equipment includes elemental autoanalyzers, C:N analyzers, gas chromatographs, mass spectrometers, total organic carbon analyzers, atomic absorption spectrometer, Europa GEOS 2002 Isotope Ratio Mass Spec, Thermal Elemental Iris DCP ICP. Field equipment includes field transport (boats, snow machines, 4 wheelers, trucks), climate stations (see proposal), portable CO2 exchange systems.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

We have secretarial services, accounting services, and a machine shop. A pool of field vehicles and computer maintenance and repair services are available on a cost-reimbursable basis.

FACILITIES, EQUIPMENT & OTHER RESOURCES

Continuation Page:

LABORATORY FACILITIES (continued):

dendrochronology, etc., as well as capabilities for training of students by long-term staff. The Taylor lab houses all equipment needed to run the molecular biology analyses detailed in this proposal, including high throughput (HT) nucleic acid extraction (high speed microplate centrifuge for 96-well plate DNA extraction kits); HT PCR (MJ Dyad thermocycler, 3 LabConco HEPA filtered clean hoods); DNA manipulation (Eppendorf microcentrifuges, vortexes, water baths, heat blocks, multichannel pipettes); electrophoresis (power supplies, agarose and acrylamide gel rigs, CCD gel documentation system); sample storage (-80C and ?20 freezers, 2 full-size refrigerators); and reagent preparation (top-loading and analytical balances, pH meter). In addition, we will have full access to the Institute of Arctic Biology Nucleic Acid Core Lab located next door, which includes additional equipment for HT DNA extraction (Qiagen BioRobot 8000, Qiagen mixer-mill, 2 additional microplate centrifuges); HT PCR (Qiagen BioRobot 8000, 2 MJ Tetrad thermocyclers); DNA visualization (an Amersham Typhoon 9200 Imager, a Molecular Devices Analyst Assay Development fluorescence, luminescence and absorbance detection system, and a Molecular Devices SPECTRAMAX plus384 spectrophotometer); DNA manipulation (Speed-Vac); and DNA sequencing (2 ABI 3130XL genetic analyzers).

COMPUTER FACILITIES (continued):

networked workstations and a three-node Beowulf computer cluster, which includes one master node and two slave nodes. Each node contains 256-MB RAM, 40-GB hard disk, and two 1.1-GHz AMD Athalon CPUs. The software available in the spatial ecology laboratory provides the GIS/spatial analysis and programming required to integrate modeling and remote sensing. Researchers also have access to the Alaska Regional Supercomputer Center (ARSC) for computational needs or as a secure storage location as well as the Bioinformatics Core of The Alaska Idea Network of Biomedical Research (INBRE) which provides shared online storage resources, systems administration support, and database consultation.

OTHER FACILITIES (continued):

Alaska Herbarium houses the most comprehensive collection of Alaskan plants in the world, and there are LTER collections of soils and plants and University Museum collections of animal tissues.

1. Journal Articles (321)

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Beier C & Chapin III FS (2008) Ecosystem services and emergent vulnerability in managed ecosystems: A geospatial decision-support tool. *Ecosystems*.

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Complete List of BNZ LTER Online Datasets (http://www.lter.uaf.edu/data_b.cfm)

Category	Filename
Biogeochemistry	Acetylene reduction and 15N2 uptake rates for Alnus tenuifolia and Alnus crispa in six different successional habitats
Biogeochemistry	Age data from Deuce and Dune Lakes, Interior Alaska
Biogeochemistry	APEX fen control plot soil temperatures, 2005-Present
Biogeochemistry	APEX fen Lowered plot soil temperatures, 2005-Present
Biogeochemistry	APEX fen Raised plot soil temperatures, 2005-Present
Biogeochemistry	Artificial Communities Experiment: Net Nitrogen Mineralization and Nitrification Potentials
Biogeochemistry	Artificial Communities Seedling Growth: Bonanza Creek Experimental Forest (planted in 1989; measured in 1992, 1995, and 2002).
Biogeochemistry	Average D and 18O isotope data for a core from the center and moat of the BBC collapse scar: Bonanza Creek Experimental Forest Flood Plains
Biogeochemistry	Biogeochemistry of Permafrosted/NonPermafrosted Watersheds in CPCRW: Summer 1995
Biogeochemistry	Biomass, %N, and %C data for the BBC collapse scar for 2003 and 2004
Biogeochemistry	Black spruce C cycling study along a temperature gradient in interior Alaska
Biogeochemistry	Black spruce needle nitrogen concentration from 1998
Biogeochemistry	Black spruce needle nitrogen concentration from 5 stands in 1999
Biogeochemistry	Characteristics and variation in lakes along a north-south gradient in Alaska
Biogeochemistry	CO2, CH4, and H2O flux data and associated environmental variables for the BBC collapse scar for 2004
Biogeochemistry	del 15N Values for Tanana River Floodplain Soils and Xylem Sap Samples
Biogeochemistry	Eight Mile Lake gradient sites: Growing season soil profile CO2 production at 10, 20, 30, and 40 cm from 2005 to 2007
Biogeochemistry	Foliage chemistry of the major tree and shrub species in Bonanza Creek Experimental Forest
Biogeochemistry	Forest floor chemistry, BCEF LTER sites, summer 1989 samples
Biogeochemistry	Ground cover and biomass projection photos for the BBC collapse scar
Biogeochemistry	Groundwater chemistry in the riparian zone of Caribou-Poker Creeks Research Watershed, Alaska, 2003
Biogeochemistry	Growing Season D and 18O isotope data for a core from the center and moat of the BBC collapse scar: Bonanza Creek Experimental Forest Flood Plains
Biogeochemistry	In situ Denitrification Rates in the Riparian Zone of Caribou-Poker Creeks Research Watershed, Alaska, 2002 - 2004
Biogeochemistry	Methane fluxes from APEX fen, 2005-2006
Biogeochemistry	N-fixation rate and leaf N content in two species of Alnus and their relationship to diversity of symbiotic Frankia
Biogeochemistry	Net ecosystem production (NEP) raw data for the coupled and uncoupled simulation for all North American black spruce grid cells (n=1758)
Biogeochemistry	Net Nitrogen Mineralization Rates for Mature Balsam Poplar and White Spruce: 1999 - 2001

Biogeochemistry	Net primary production, heterotrophic respiration, and net ecoystem production out from TEM outputs compared with Tower data: 1899 - 2100
Biogeochemistry	Net primary production, heterotrophic respiration, and net ecoystem production out from TEM outputs: 1899 - 2100
Biogeochemistry	Nitrogen production and foliage biomass from LTER sites 1989
Biogeochemistry	Paleoecological pollen data from Deuce and Dune Lakes, Interior Alaska
Biogeochemistry	Patterns of and controls over nitrogen inputs by green alder (Alnus viridis spp. fruticosa) to a secondary successional chronosequence in interior Alaska I - N2 Fixation and Soil Temperature
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