From the Vault: Historical Perspectives on Climate Sensitivity Research by the BNZ LTER Over the Past 30 yrs

BNZ LTER - Award History

1987-1992: LTER1: *Successional Processes in Taiga Forests of Interior Alaska: A Long-Term Ecological Research Program for the Study of Controls of Subarctic Forest Development* (PI: Van Cleve)

1992-1997: LTER2*: Successional Processes in Taiga Forests of Interior Alaska: A Long-Term Ecological Research Program for the Study of Controls of Subarctic Forest Development* (PI: Van Cleve)

1998-2000: LTER3a: *Interaction of Multiple Disturbances with Climate in the Alaskan Boreal Forest* (PI: Chapin)

2000-2004: LTER3b: *Interaction of Multiple Disturbances with Climate in the Alaskan Boreal Forest* (PI: Chapin)

2004-2006: LTER 4a: *The Dynamics of Change in Alaska's Boreal Forests: Resilience and Vulnerability in Response to Climate Warming* (PI: Chapin)

2006-2010: LTER 4b: *The Dynamics of Change in Alaska's Boreal Forests: Resilience and Vulnerability in Response to Climate Warming* (PI: Chapin)

2011-2017: LTER 5: *Regional Consequences of Changing Climate-Disturbance Interactions for the Resilience of Alaska's Boreal Forest* (PI: Ruess)

2017-2023: LTER6: *Cross-Scale Controls Over Responses of the Alaskan Boreal Forest to Changing Disturbance Regimes* (PI: Ruess)

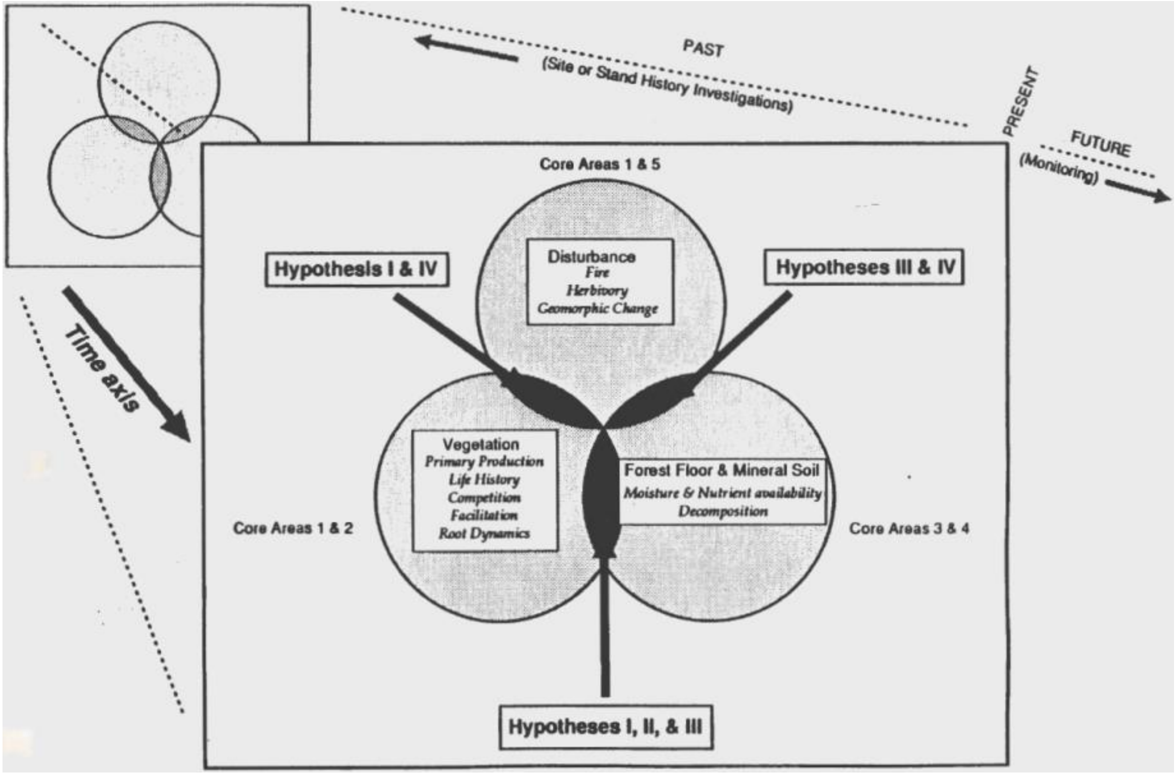
LTER 1 & 2 (1987-1992; 1992-1998): *Successional Processes in Taiga Forests of Interior Alaska: A Long-Term Ecological Research Program for the Study of Controls of Subarctic Forest Development*

H1 = Successional = life history traits modified by facilitative and competitive interactions

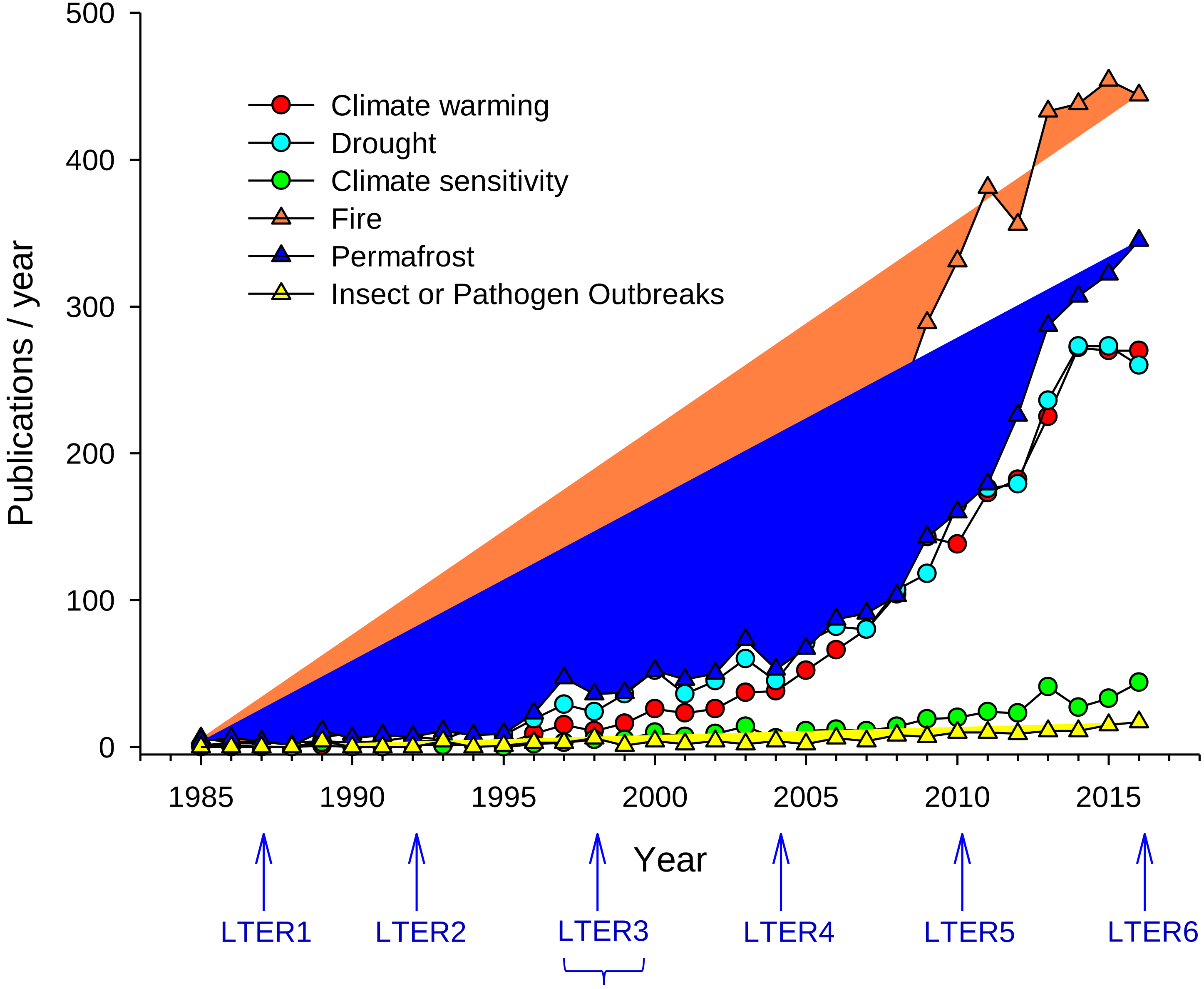
H2 = Vegetation-caused changes in resource (light, nutrients, moisture) availability during succession controls ecosystem function

H3 = Successional declines in labile C affects on SOM mineralization, nutrient availability and plant growth

H4 = Herbivores promotes replacement of palatable species by unpalatable species.



SCOPUS search: (Alaska + Boreal + __)



How do climate and disturbance regime alter the functioning of the boreal forest?

LTER 3a (1998-2000): *Interaction of Multiple Disturbances with Climate in the Alaskan Boreal Forest*

Task 1. Document climate: The microclimate to which community and ecosystem processes respond is determined more strongly by disturbance and vegetation than by macroclimate.

Monitor macro & microclimate/permafrost,
Initiate Eddy Flux at CPCRW

Task 2. Document the disturbance regime: Historic and contemporary feedbacks among major boreal disturbances (fire size and probability, logging, insects, and flooding) result in a highly interactive disturbance regime that responds nonlinearly to changes in climate and land use.

Climate warming effects on fire probability & size, insect outbreaks
Where is logging and what are interactions between logging, fire, & insects
landscape scale feedbacks affect the probability of these occurrences (e.g., changes in stand types, effects of fire on lightening strikes)
Paleo-reconstruction of fire-insect interactions

Task 3. Document impacts of climate and disturbance regime on population dynamics and diversity: Type and severity of disturbance influence population dynamics, community composition, and diversity more strongly than does climate.

Disturbance type & severity + seed avail = successional trajectory

Grassland occurrence affected by insects and logging

Biotic/abiotic controls over growth and survival at treeline, including
reconstructing past fire impacts on treeline establishment

Warm/dry good for insects/pathogens but bad for moose

Large and small mammals more sensitive to disturbance than climate

B-diversity strongly affected by landscape structure – affecting speed,
trajectory and endpoints of succession

Task 4. Document effects of climate and disturbance regime on productivity, biogeochemistry, and C cycling: At the stand level, C balance is controlled by vegetation & soil environment, and at the landscape scale by disturbance.

Climate variability causes changes in net C balance of late successional ecosystems because NPP is stimulated by moisture supply, whereas decomposition is stimulated by temperature.

Climatic and nutrient controls over net ecosystem C balance shifts from controls over plant production in early succession to decomposition in late succession.

Disturbances impact on microbial processes, NPP, BG/AG C partitioning and NEE operate through effects on vegetation, soil moisture, temperature, litter chemistry, and stability of permafrost - and vary with landscape position

Big focus on C cycling BS – including role of mosses

Changes in biologically available soil C since fire, ^{14}C to look at turnover time of various SOM pools

Herbivory affect C dynamics in early and mid-succession

Task 5. Document impacts of climate and disturbance regime on hydrologic and aquatic processes: Hydrologic linkages between land and water and the resulting processes in aquatic ecosystems are influenced more strongly by disturbance regime than by climate.

Soil moisture and surface temperature are controlled by topographic position and vegetation; their integration across the landscape causes the greatest feedbacks to local and regional climate.

Fire increases thaw depth and thus groundwater flow through mineral soil, leading to reduced DOC and increased cation input to streams (FROSTFIRE)

Nutrient input to aquatic systems, autochthonous production, and secondary production are affected more strongly by fire than by the environmental differences between permafrost-dominated and permafrost- free sites

Fire enhances fish production by increasing water temperatures, nutrients and aquatic NPP, fueling greater secondary production (benthic macroinvertebrates).

Task 6. Document the long-term record of climate, disturbance regime, vegetation, and ecosystem processes: Ecosystem response to climatic change depends on the state of each component of the system (climate, vegetation, and soils) and the susceptibility of individual processes to change.

Rates of tree growth have changed substantially in the past 300 years in response to climate, but climate has different effects on the major forest dominants and therefore is likely to alter future vegetation composition (reconstructing white spruce growth along ATP transect)

The nature of stand replacement following disturbance is sensitive to climate and disturbance regime (reconstructing fire return intervals and vegetation across the landscape)

Rapid climatic change generates a disequilibrium between climate and ecosystem processes, resulting first in changes in productivity, then in species composition, and most slowly in pools of soil organic carbon (test using late-Holocene lake sediment records)

Task 7. Temporal and spatial extrapolation: Over the long term, boreal carbon dynamics are more sensitive to the effects of disturbance than to the effects of climate on mature ecosystems.

Need to improve the mechanistic understanding of boreal C dynamics in order to model climate feedbacks.

Develop, test, and apply a Dynamic Vegetation Model (DVM) (from TEM) to dynamically model how the interaction of disturbance history, forest type, topography, and climate influence 1) the timing, extent and severity of disturbance, 2) the trajectory of vegetation and animal succession, and 3) the biogeochemical dynamics of succession.

Develop regional maps of climate, topography and vegetation, and assess the historical impacts of disturbances (fire, animals, insects) on vegetation across the landscape

Includes fire module based on integrating timing, extent and severity of fire with veg characteristics (flammability characteristics) and subsequent successional processes.

LTER 3b (2000-2004): ***Interaction of Multiple Disturbances with Climate in the Alaskan Boreal Forest***

3 Themes:

Forest Dynamics: Relative importance of historical legacies, stochastic processes, and species effects on successional trajectories and the sensitivity of these trajectories to climate

The Changing Boreal C Cycle: Focus on successional changes in vegetation and microclimate, and studying role of climate through its direct (NPP and Rh) and indirect (changes in species composition and their effects on biogeochemistry).

Regional and Landscape Controls over Disturbance Regime: Focuses on regional and landscape processes that are responsible for the timing, extent, and severity of disturbance.

Regional and Landscape Controls over Disturbance Regime: Focuses on regional and landscape processes that are responsible for the timing, extent, and severity of disturbance.

Large fires only occur in BS, warming increases fire probability

Fire regime is controlled more by flammability than ignition (lightening strikes & area burned not correlated

Disturbance is more important than climate in controlling thermokarst

Floodplains have for frequent and smaller disturbances than uplands – shrub patchiness good for herbivores

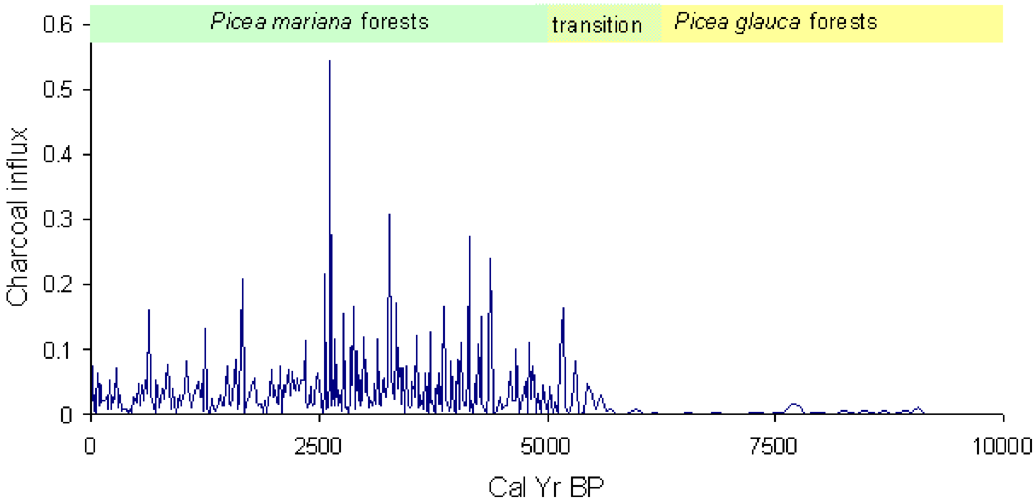
Watershed hydrology/biogeochemistry driven by microclimate-disturbance interactions

3 Synthesis Efforts:

Species effects on ecosystem and landscape processes = how species identity and diversity influence biogeochemistry and disturbance regime

Spatio-temporal scaling = conceptual basis for linking process and pattern. 1) Stand-level models (herbivores and tree pop dynamics, 2) Soil-thermal models of permafrost thaw, 3) DVM, 4) ALFRESCO, 5) TEM

Ecosystem sustainability = how the positive and negative feedbacks influence the sensitivity of ecosystems to perturbations such as changes in climate and disturbance regime.



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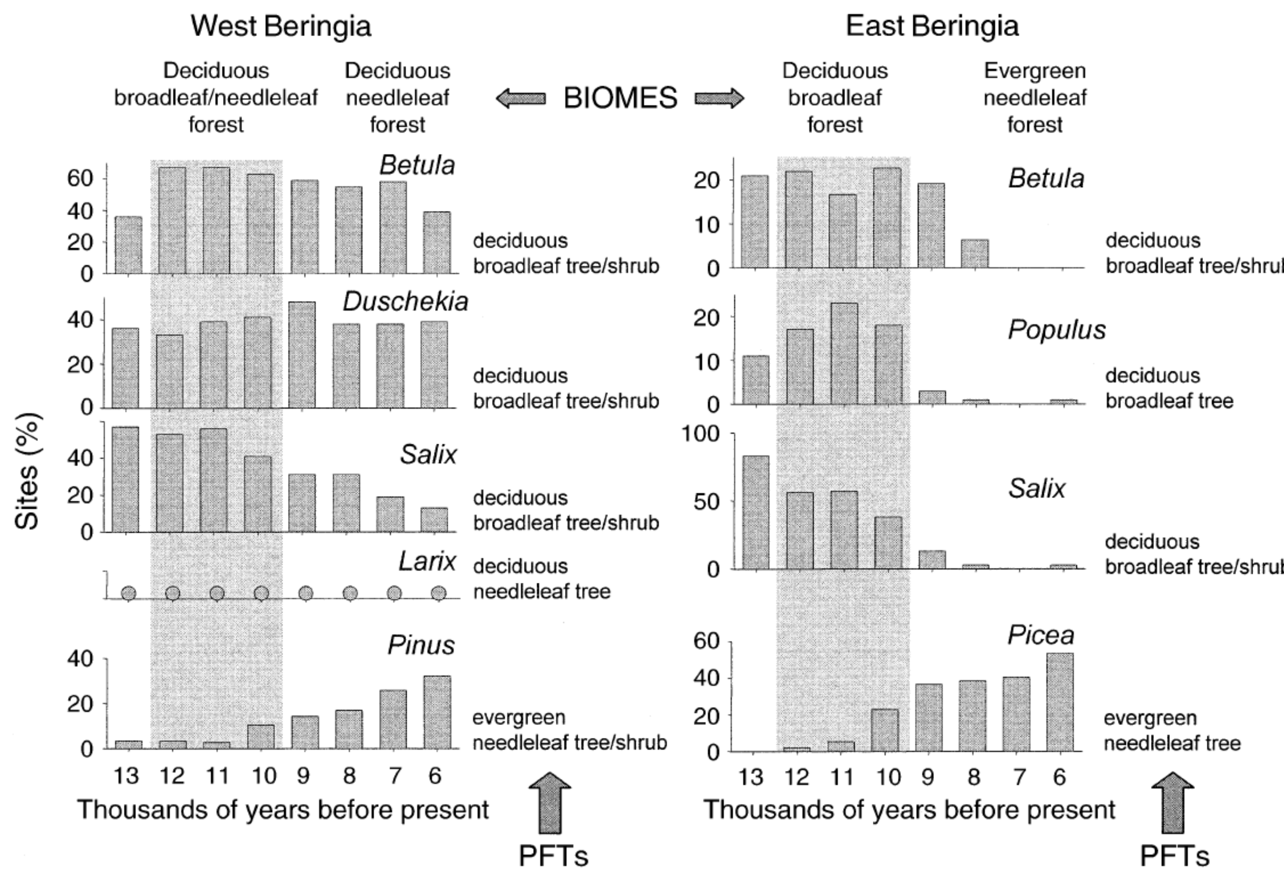

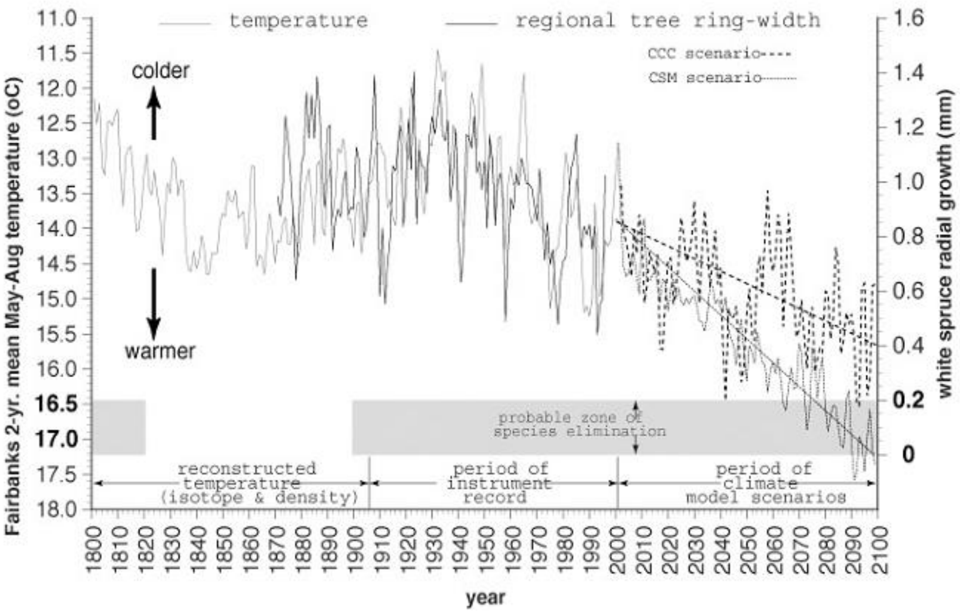

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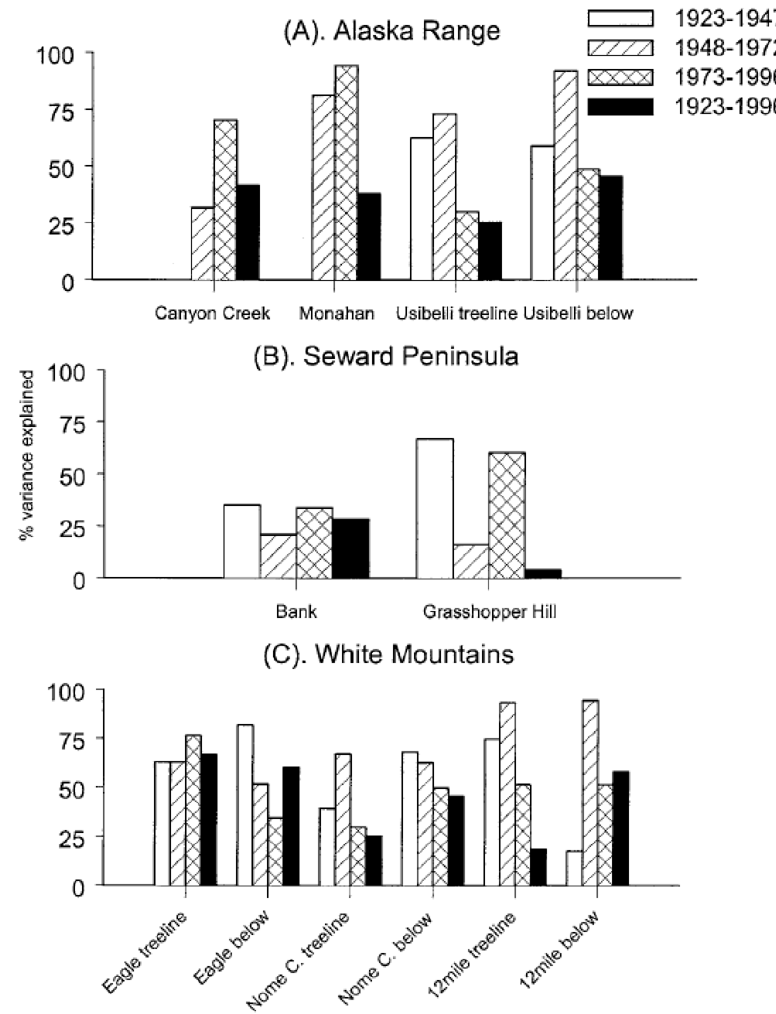

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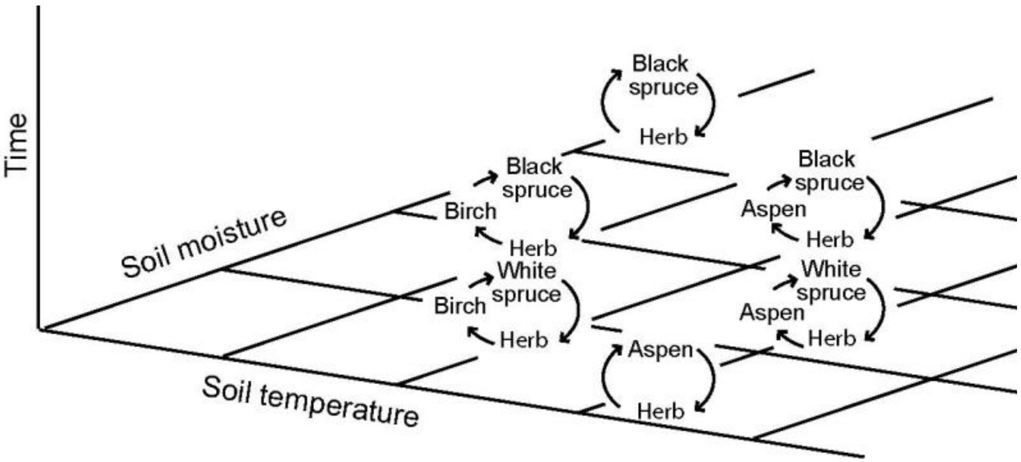

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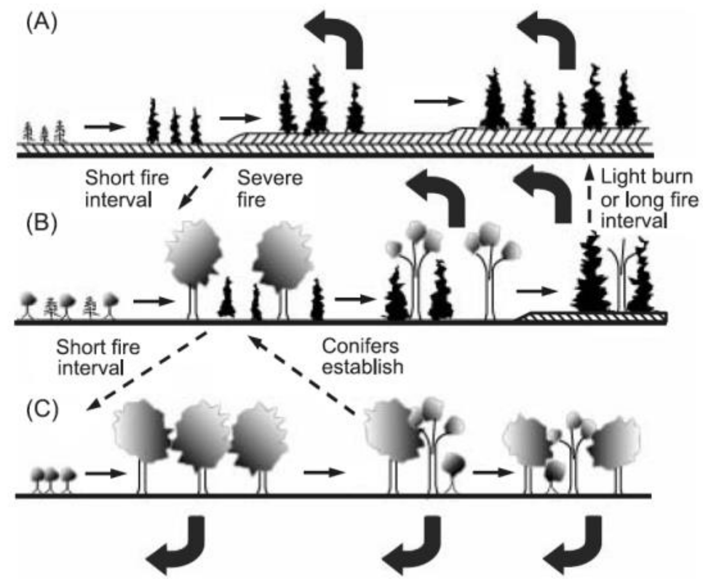

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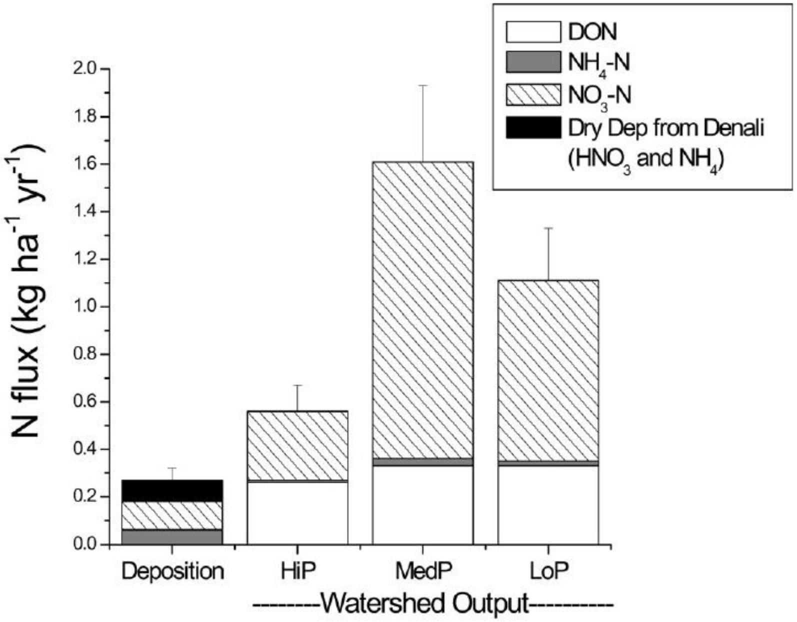
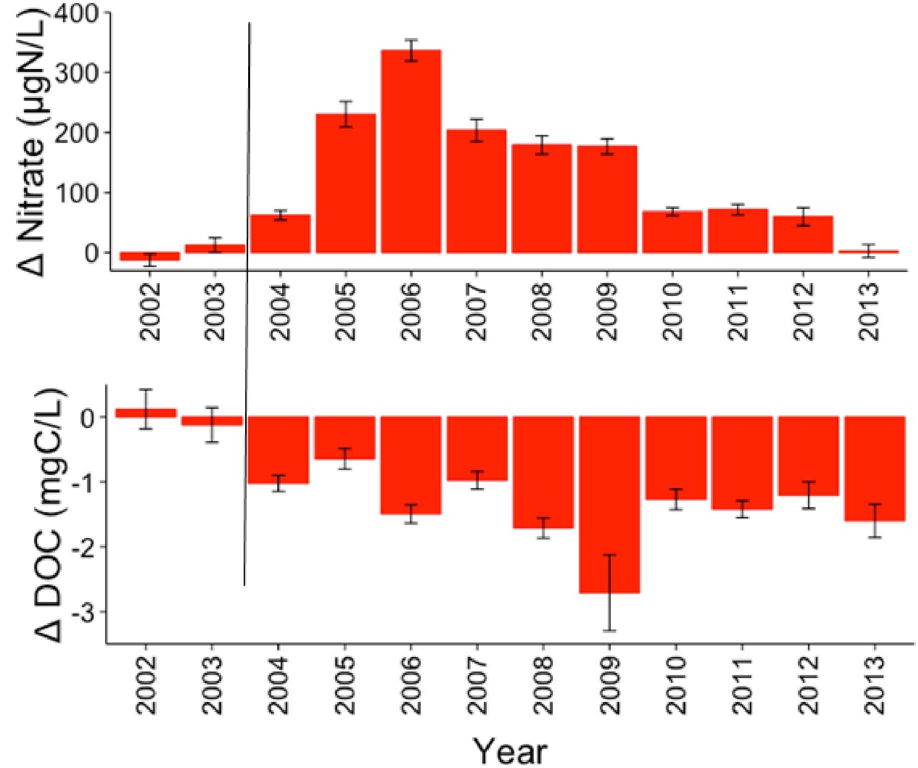


Figure 6. Annual nitrogen deposition and export in streamflow from the high-, medium-, and low-permafrost watersheds. Input represents both wet and dry deposition. Output in streamflow is represented by DIN and DON.

FROSTFIRE effects on stream chemistry



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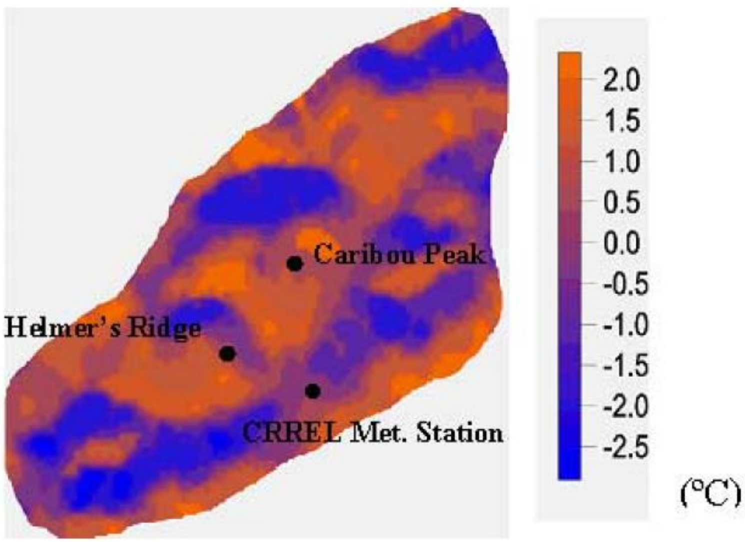
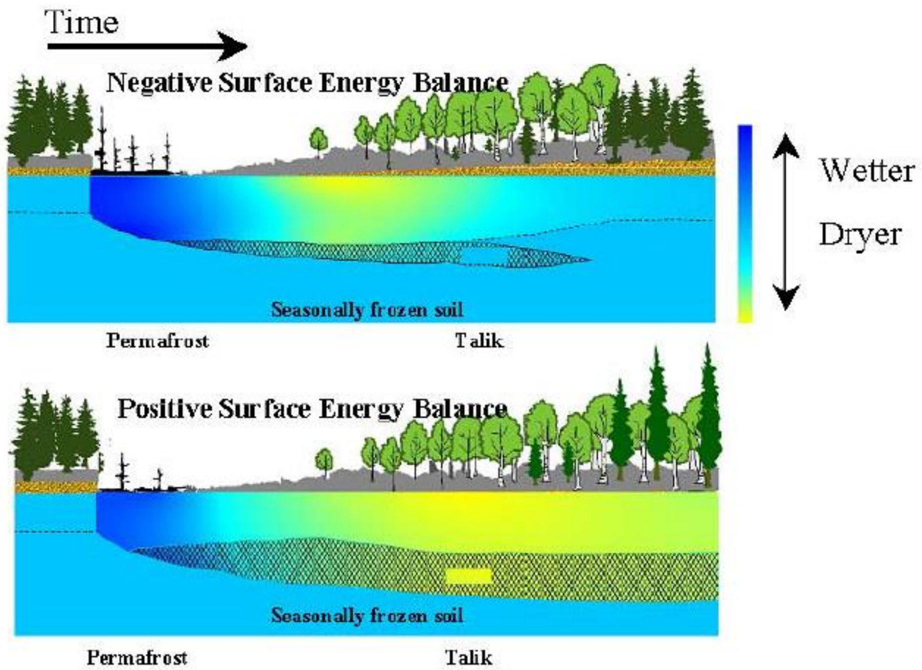
Modeling surface energy balance in regions of discontinuous permafrost



Permafrost/talik response to fire



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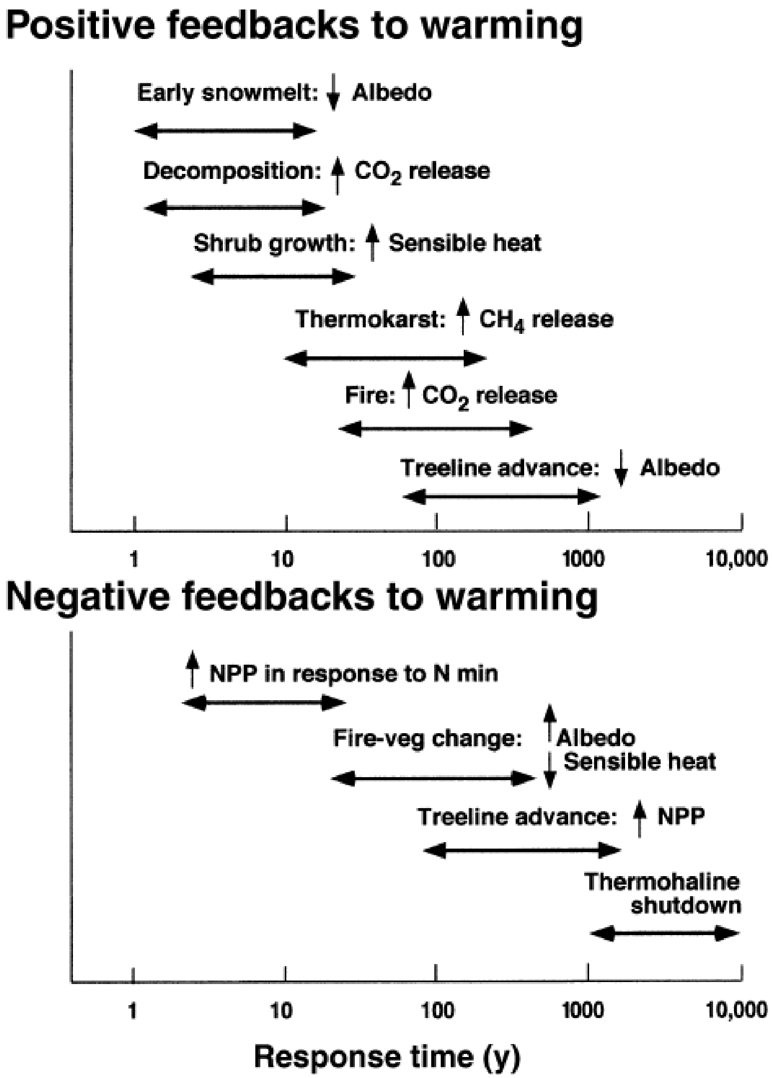

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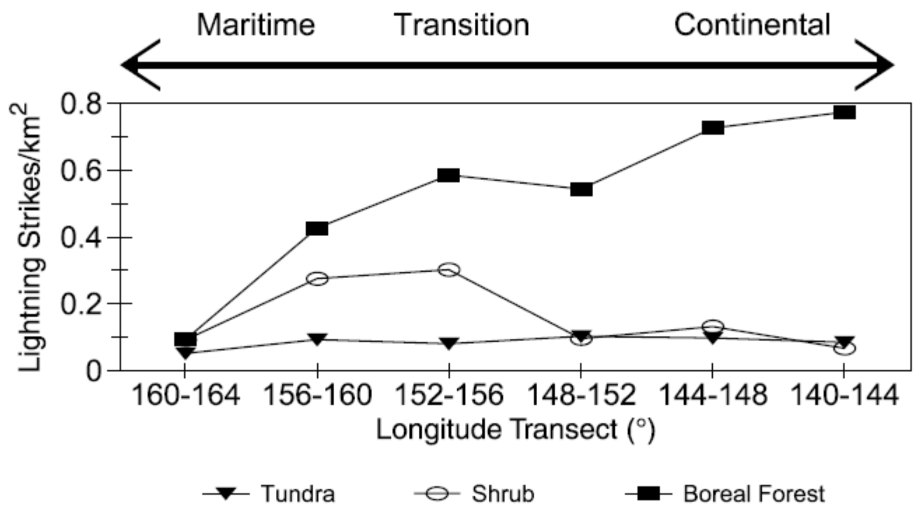

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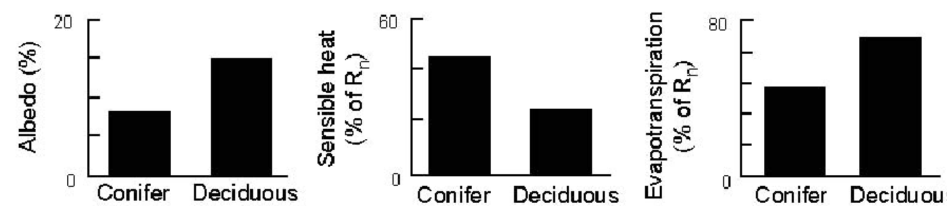

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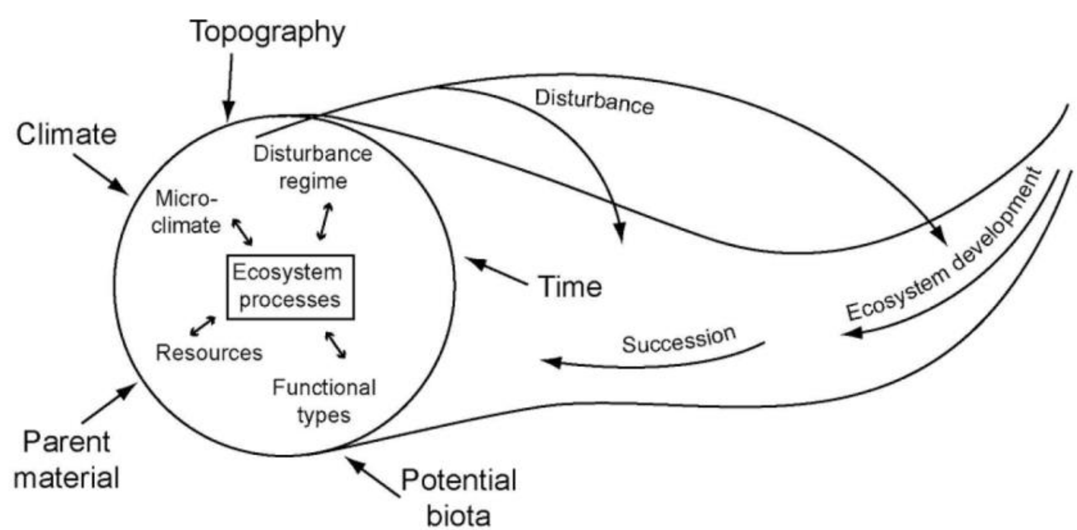
LTER4b (2004-2006): ***The Dynamics of Change in Alaska's Boreal Forests: Resilience and Vulnerability in Response to Climate Warming***

How are boreal ecosystems responding, both gradually and abruptly, to climate warming, and what new landscape patterns are emerging?

1) What currently controls and constrains the resilience of Alaska's boreal forest?
2) What recent and projected changes in drivers make this system vulnerable to change?
3) How do factors influencing the balance among alternative states respond to recent and projected changes in drivers?

3 Themes:

Forest Dynamics
Biogeochemistry
Landscape Dynamics

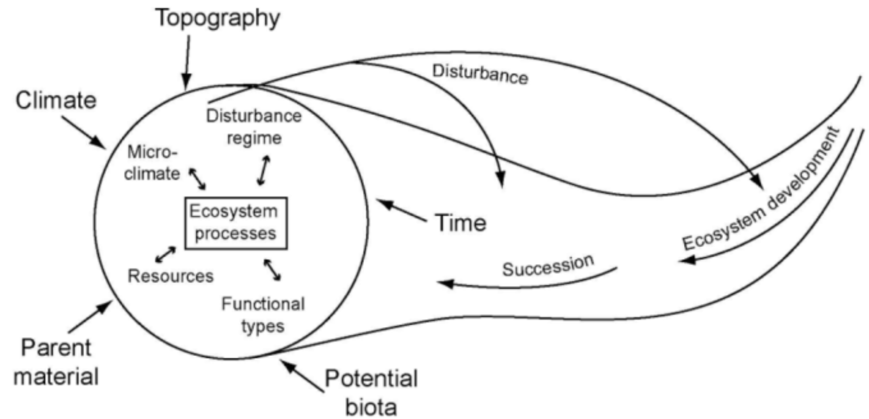


Integrating state factors, interactive controls, legacies, and resilience theory into ecosystem development and change (Chapin et al. 2006)

LTER4a (2006-2010): How are boreal ecosystems responding, both gradually and abruptly, to climate warming, and what new landscape patterns are emerging?

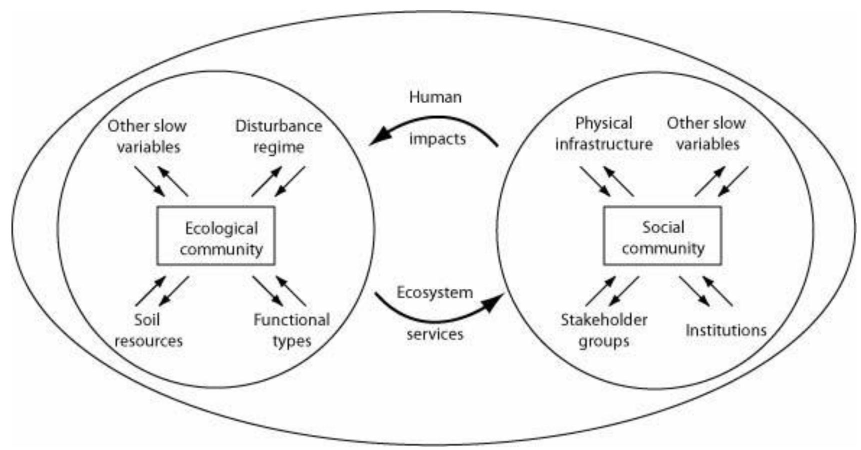
4 Themes:

Climate Sensitivity
Successional Dynamics
Threshold Changes
Integration and Synthesis



Integrating state factors, interactive controls, legacies, and resilience theory into ecosystem development and change (Chapin et al. 2006)

Societal consequences by identifying past and future changes in subsistence resources (provisioning services) and climate feedbacks (regulating services).

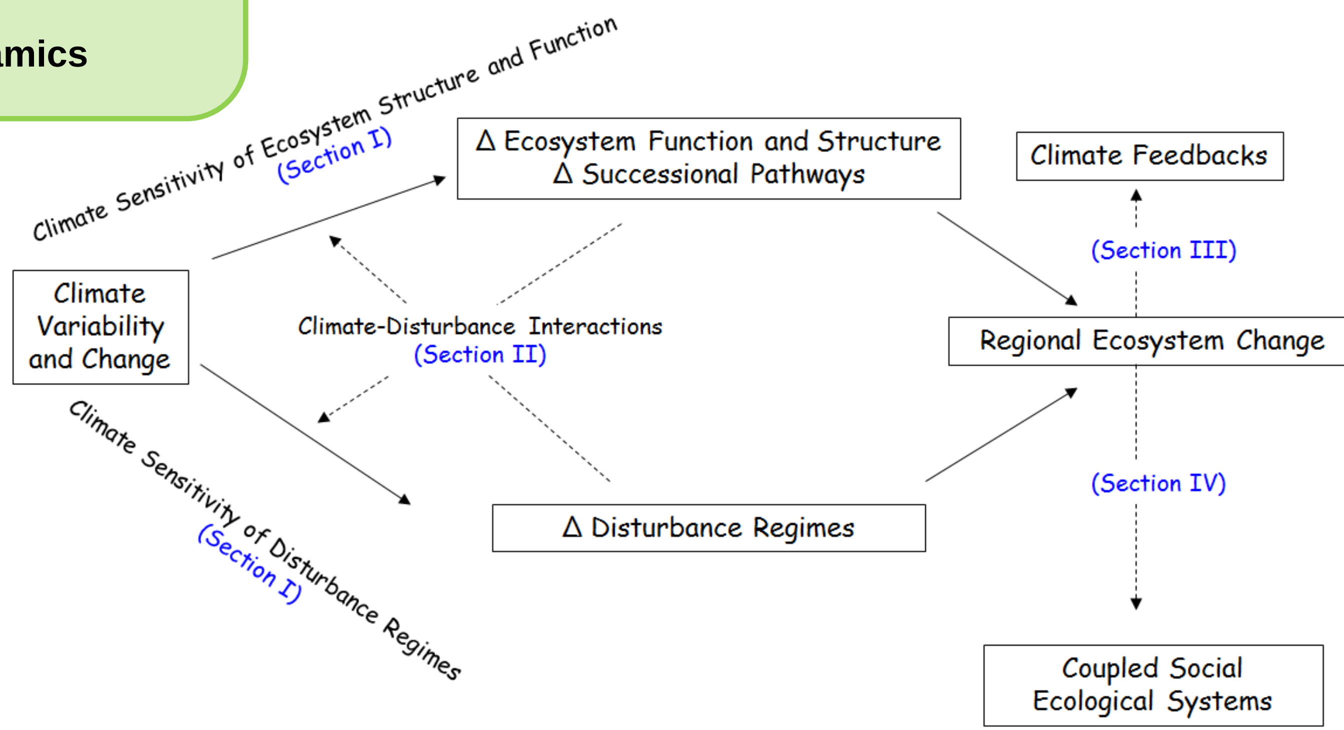


BNZ LTER framework for studying social-ecological systems

LTER5 (2011-2017): *Regional Consequences of Changing Climate-Disturbance Interactions for the Resilience of Alaska's Boreal Forest*

4 Themes:

Climate Sensitivity
Climate Disturbance Interactions
Climate Feedbacks
Social-Ecological Dynamics



LTER5 (2017-2023): *Cross-Scale Controls Over Responses of the Alaskan Boreal Forest to Changing Disturbance Regimes*

5 Themes:

Climate Sensitivity
Climate Disturbance Interactions
Landscape Heterogeneity - Climate Feedbacks
Social-Ecological Dynamics
Resource Management Co-Production