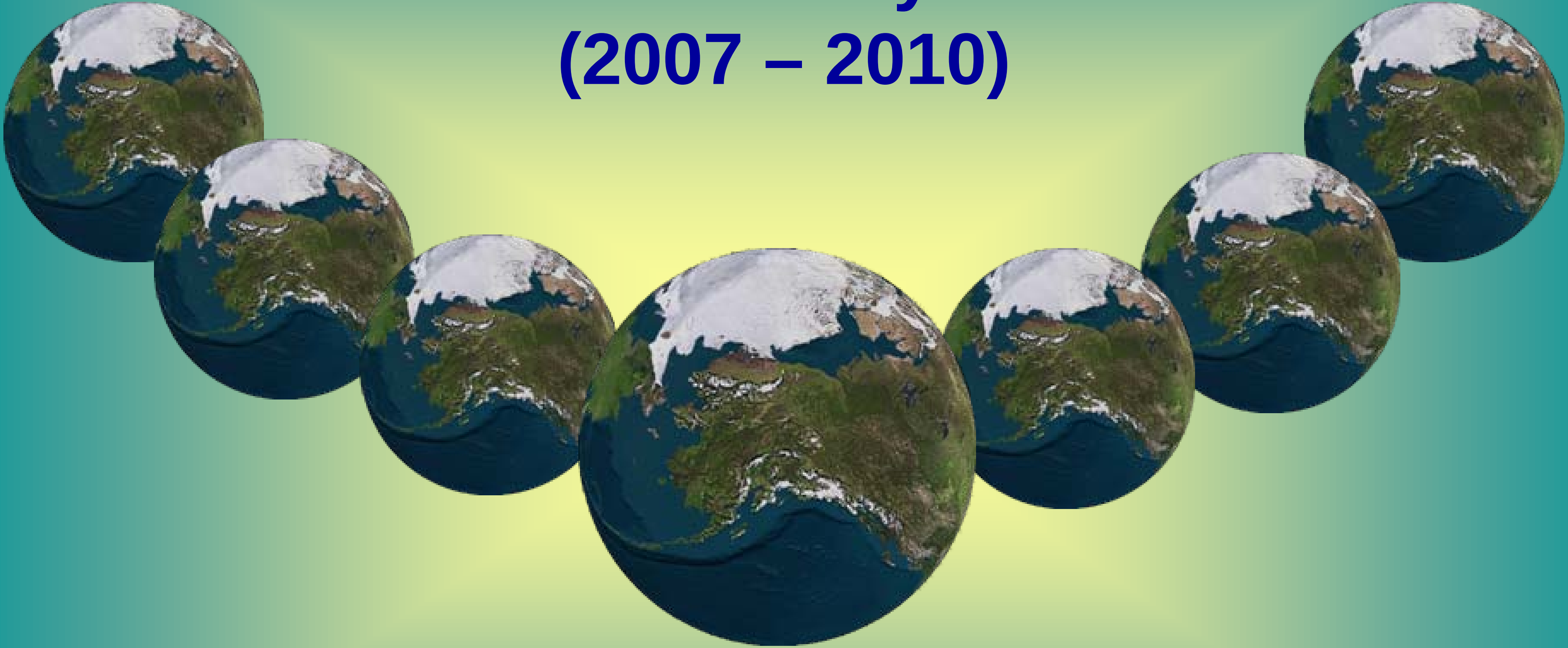
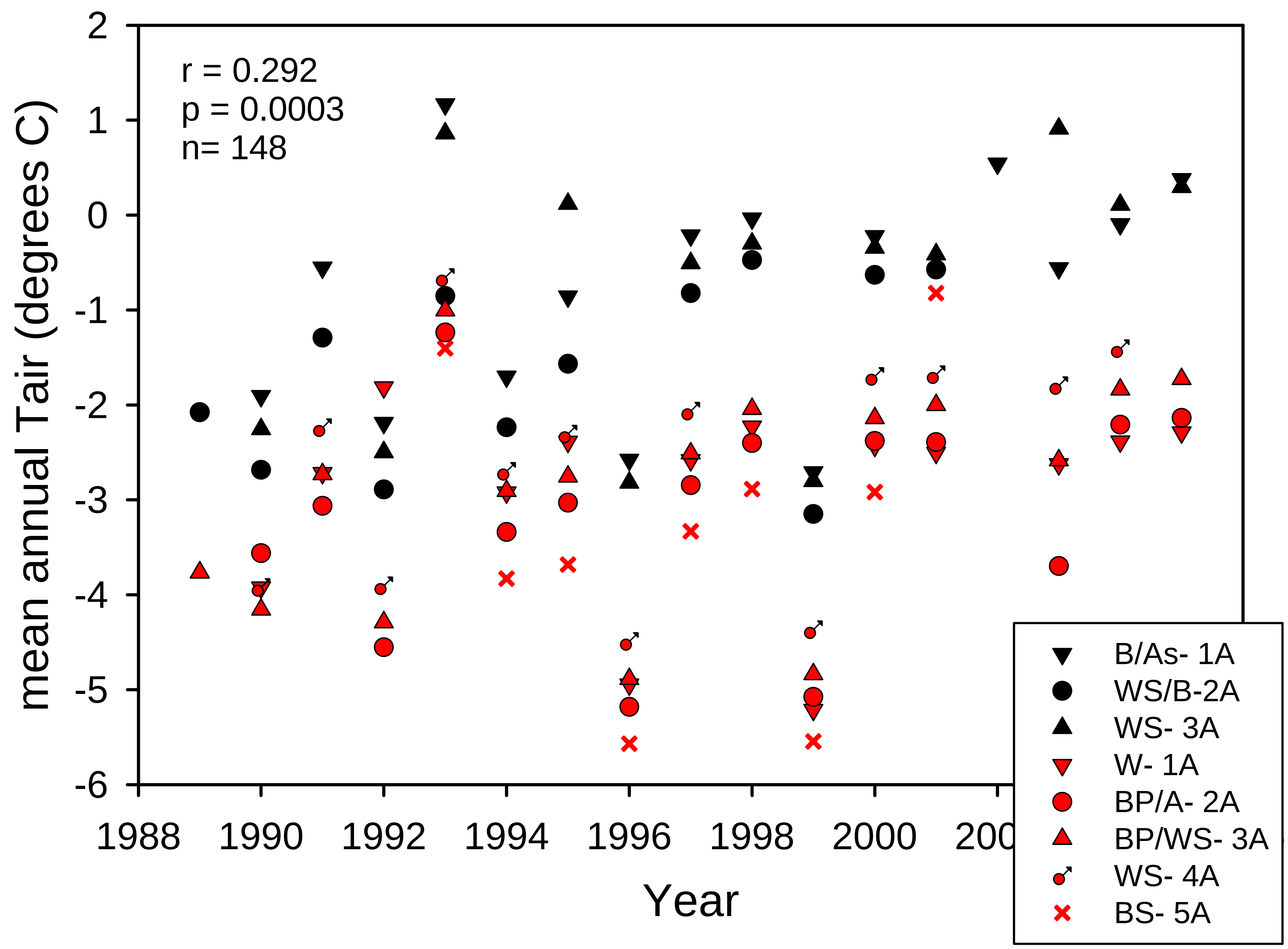
BNZ LTER
Climate Sensitivity Research
(2007 – 2010)



A. David McGuire

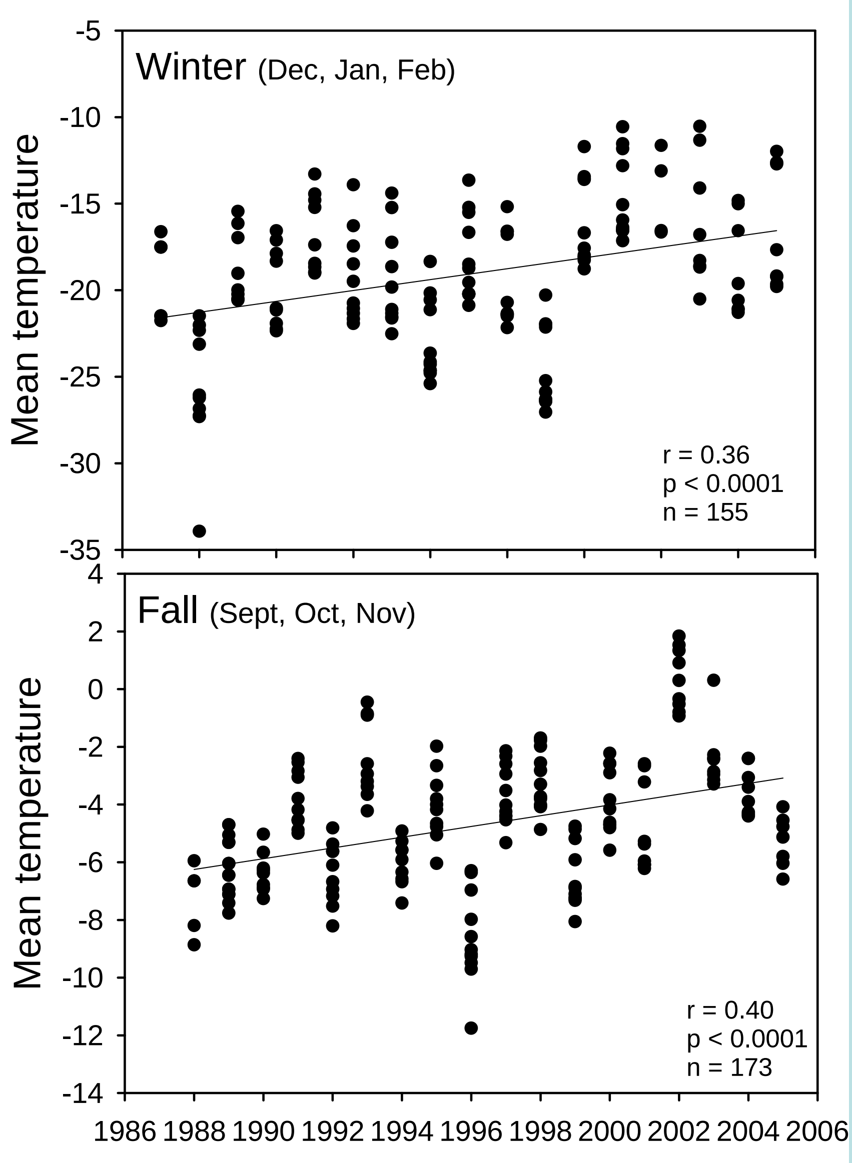
University of Alaska Fairbanks



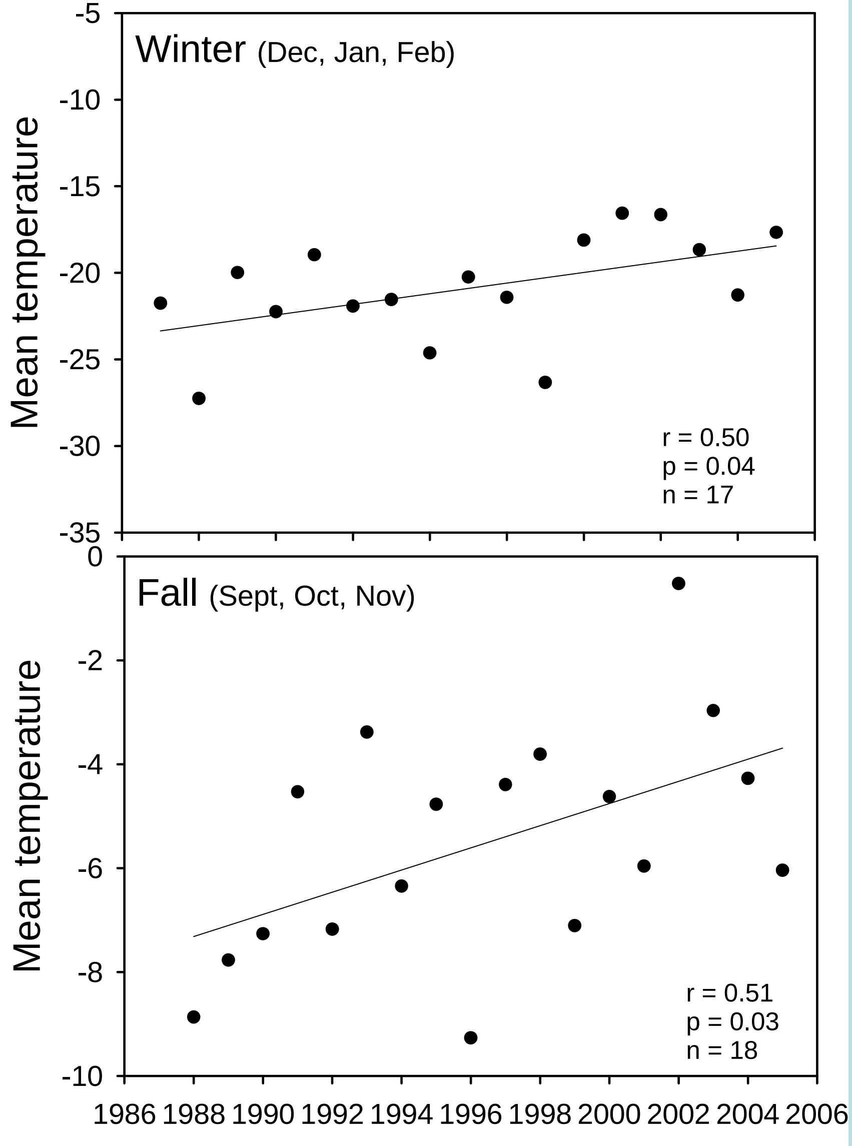
B-birch,
WS-white spruce, W-willow
BP-balsam poplar, A-alder
BS-black spruce

Black symbols-upland sites
Red symbols-floodplain sites

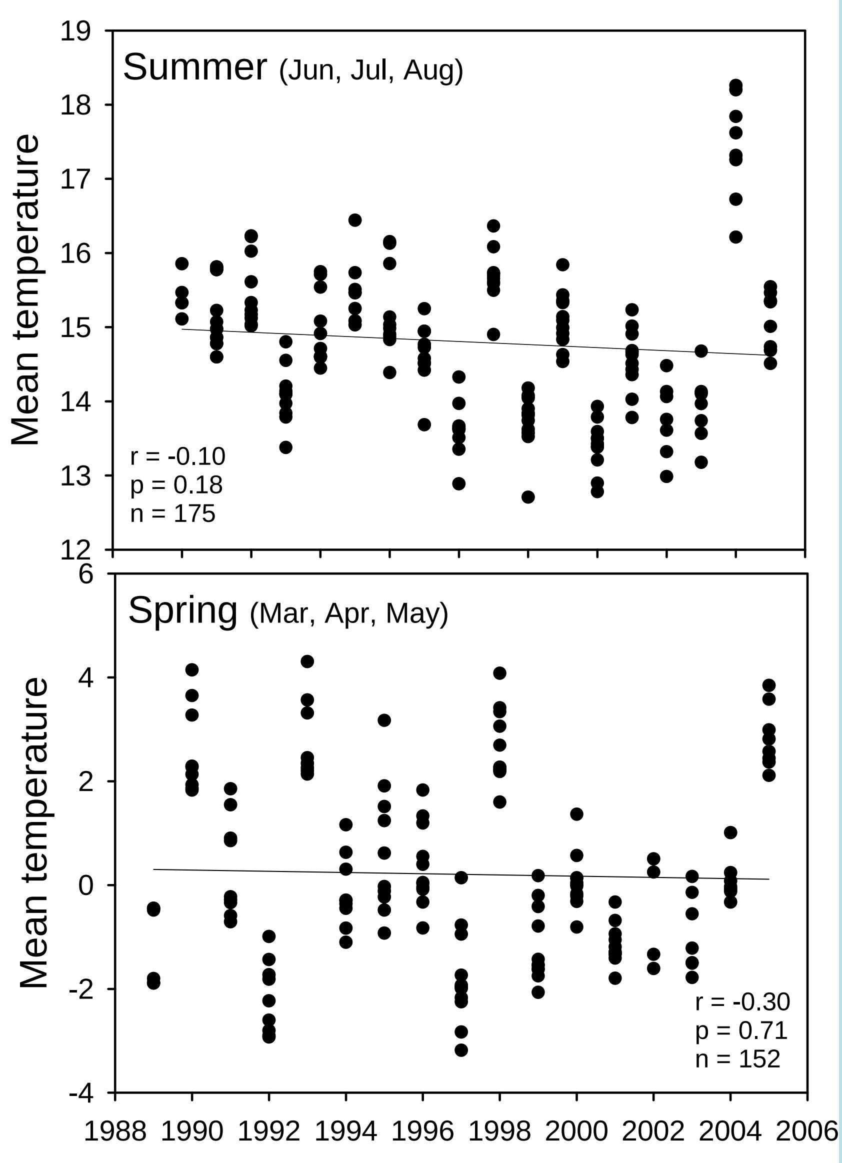
All sites



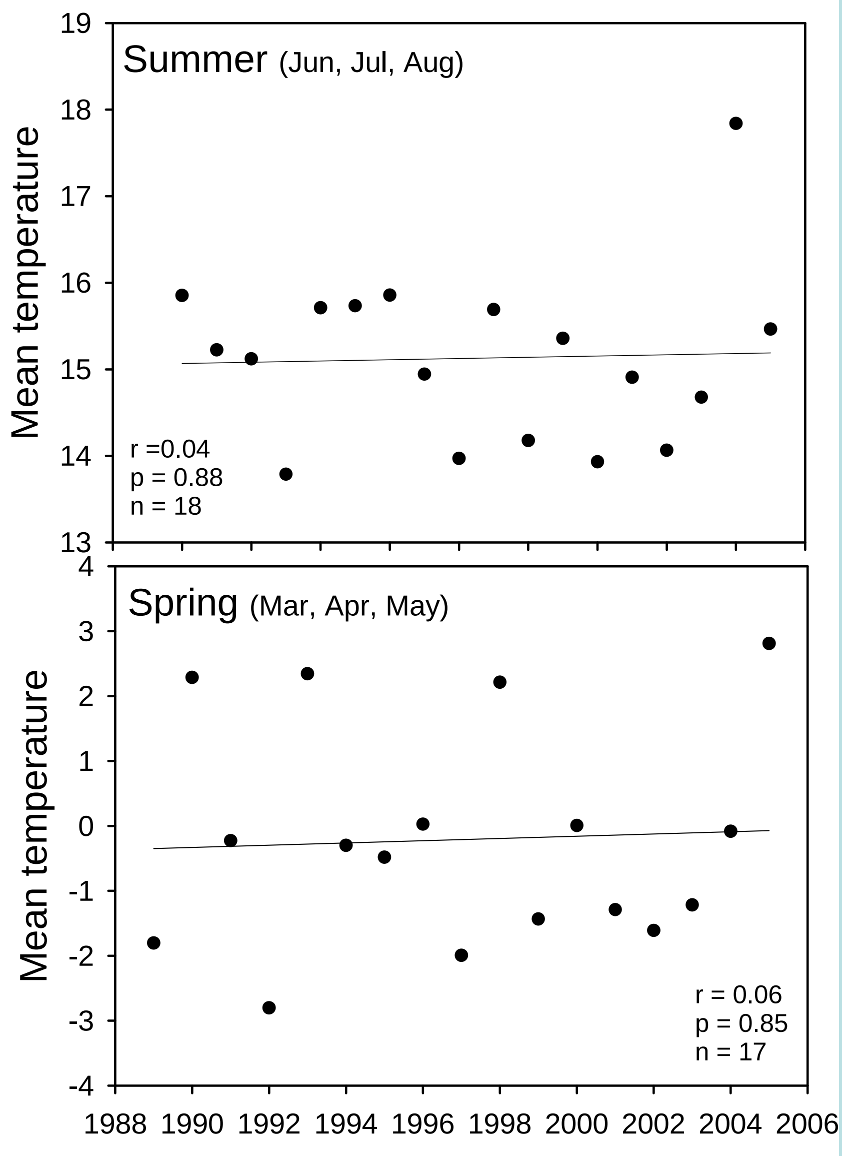
Floodplain weather station,
mowed area

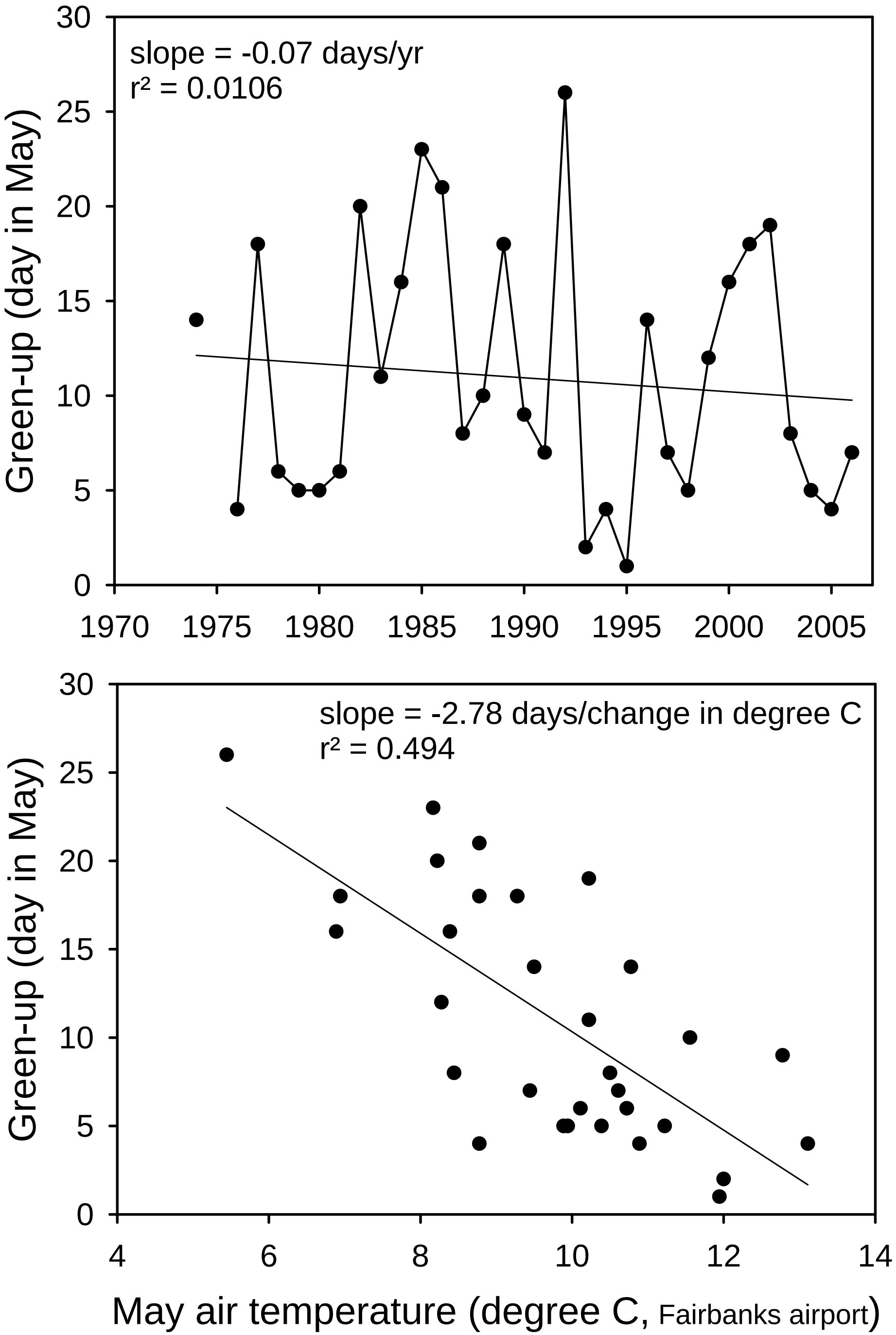


All sites



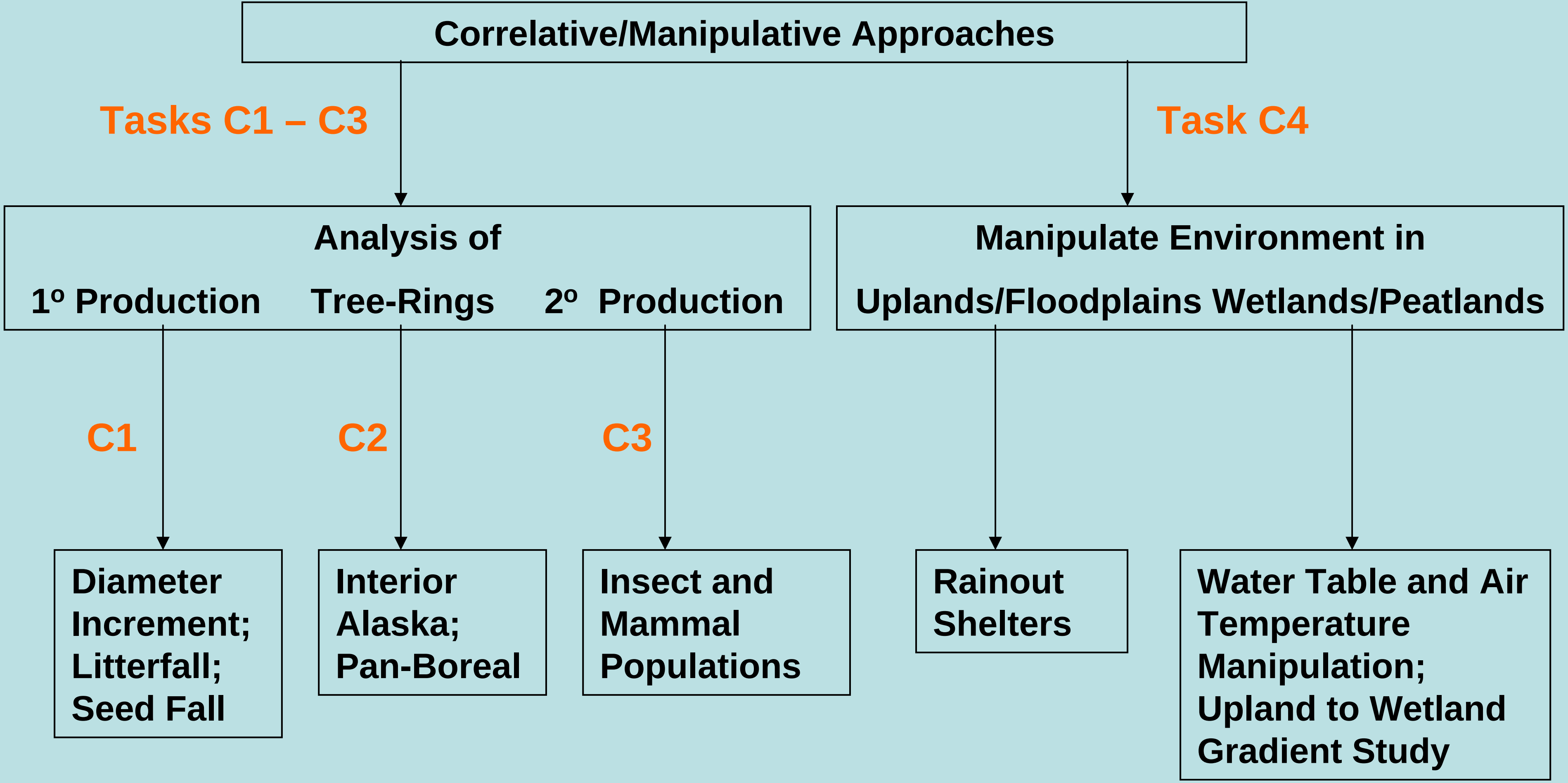
Floodplain weather station,
mowed area




slope = -0.07 days/yr
r² = 0.0106
Green-up (day in May)
0
5
10
15
20
25
30
1970
1975
1980
1985
1990
1995
2000
2005
slope = -2.78 days/change in degree C
r² = 0.494
Green-up (day in May)
0
5
10
15
20
25
30
4
6
8
10
12
14
May air temperature (degree C, Fairbanks airport)

Climate Sensitivity

1) How has climate change altered the physical environment of the BNZ LTER site and how have different stand types (conifer vs. deciduous; upland vs. floodplain vs. wetland) differed in their responses to the direct and indirect effects of summer warming?



Correlative/Manipulative Approaches

Tasks C1 – C3

Task C4

Analysis of

1^{o} Production Tree-Rings 2^{o} Production

Manipulate Environment in

Uplands/Floodplains Wetlands/Peatlands

C1

C2

C3

Diameter Increment; Litterfall; Seed Fall

Interior Alaska; Pan-Boreal

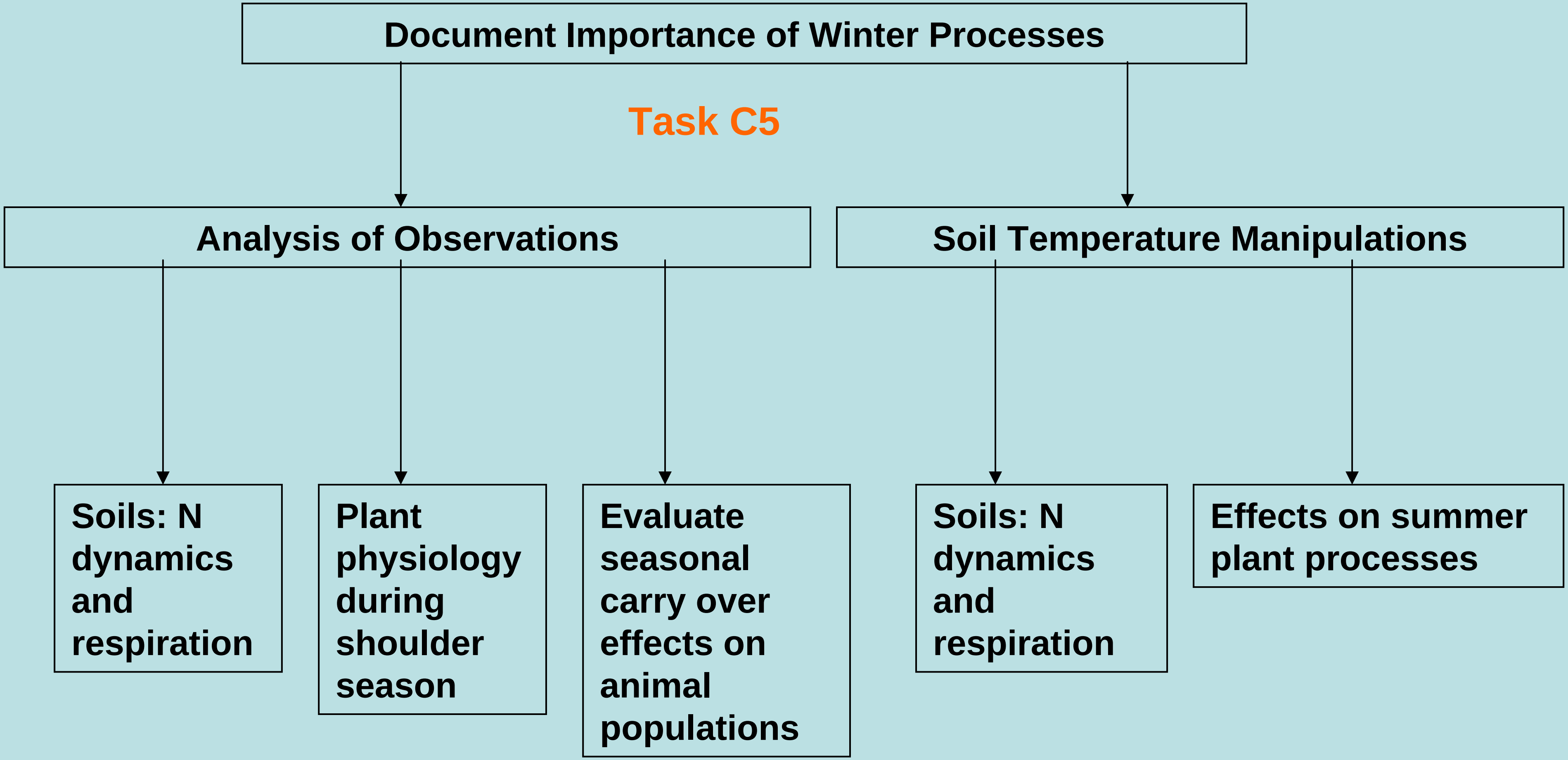
Insect and Mammal Populations

Rainout Shelters

Water Table and Air Temperature Manipulation; Upland to Wetland Gradient Study

Climate Sensitivity

1) How does winter warming influence ecosystem processes in Alaska’s boreal forest?



Document Importance of Winter Processes

Task C5

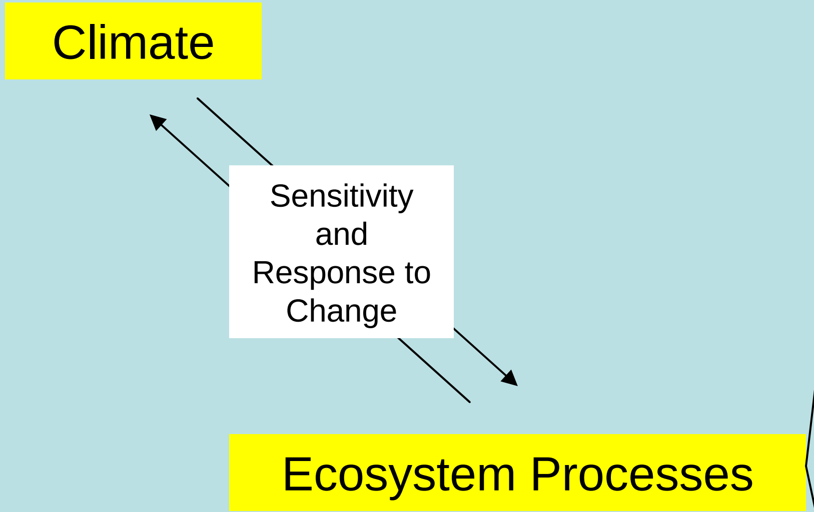
Analysis of Observations

- **Soils: N dynamics and respiration**
- **Plant physiology during shoulder season**
- **Evaluate seasonal carry over effects on animal populations**

Soil Temperature Manipulations

- **Soils: N dynamics and respiration**
- **Effects on summer plant processes**

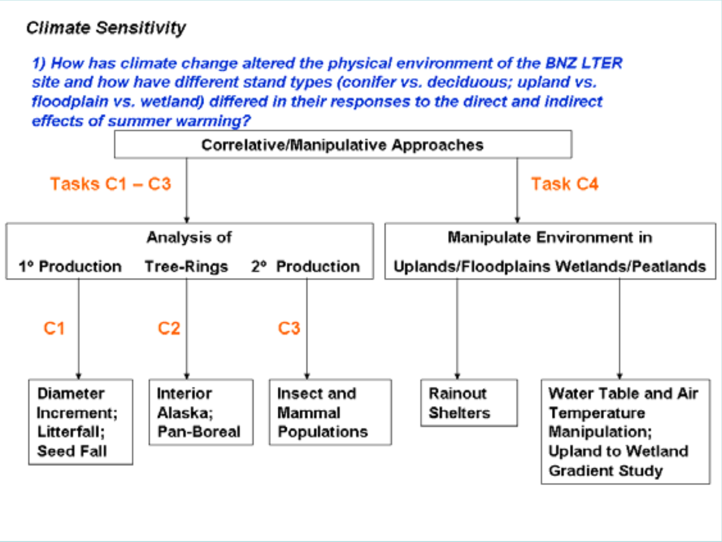
Climate Sensitivity



Climate

Sensitivity and Response to Change

Ecosystem Processes



Climate Sensitivity

1) How has climate change altered the physical environment of the BNZ LTER site and how have different stand types (conifer vs. deciduous; upland vs. floodplain vs. wetland) differed in their responses to the direct and indirect effects of summer warming?

Correlative/Manipulative Approaches

Tasks C1 – C3

Task C4

Analysis of
1° Production Tree-Rings 2° Production

Manipulate Environment in
Uplands/Floodplains Wetlands/Peatlands

C1

C2

C3

Diameter Increment; Litterfall; Seed Fall

Interior Alaska; Pan-Boreal

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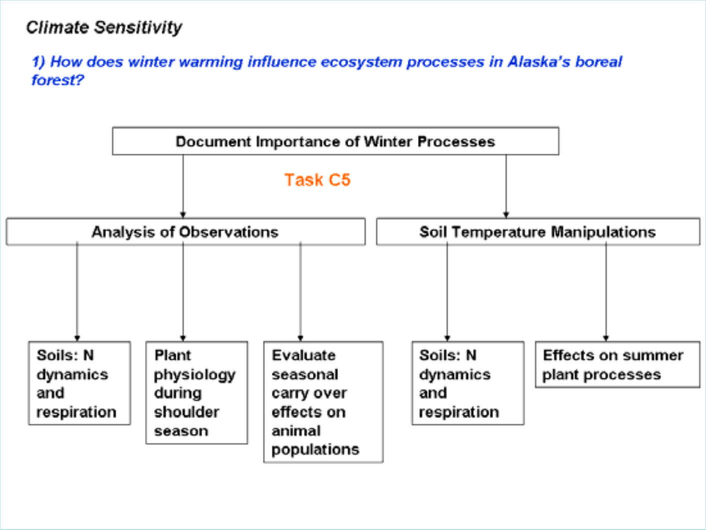


Climate Sensitivity

1) How does winter warming influence ecosystem processes in Alaska's boreal forest?

Document Importance of Winter Processes

Task C5

Analysis of Observations

Soil Temperature Manipulations

Soils: N dynamics and respiration

Plant physiology during shoulder season

Evaluate seasonal carry over effects on animal populations

Soils: N dynamics and respiration

Effects on summer plant processes

BNZ LTER Monthly Talks in 2006 to
(1) Exchange ideas on climate sensitivity
(2) Explore BNZ LTER data re climate sensitivity

- Warming experiments past, present, and future (Trish Wurtz)
- Interspecific differences in climate sensitivity (Andi Lloyd, Teresa Hollingsworth, and Joy Clein)
- Thermokarst (Jay Jones, Ted Schuur, Vladimir Romanovsky)
- Cross site DIN retention (Evan Kane)
- Boreal biome root allocation and C cycling (Jason Vogel)
- Post-fire respiration sensitivity (Eric Kasischke, Dave Valentine)
- Rainout shelter results (John Yarie)
- Analysis of how “summer” measurements depend on “winter” issues (Jen Harden, Eugenie Euskirchen, Joy Clein)

Climate Sensitivity Research Tasks

C1 - ***How has variability in summer climate affects primary production, litter fall, and seed fall at BNZ LTER sites*?** **(McGuire, J. Hollingsworth, J. Clein, R. Ruess)**

PI responsibilities for analyzing BNZ “core data”

- Climate Data – *McGuire*
- Frost Probe Data - *Romanovsky*
- Watershed Hydrology Data – *Jones*
- NRCS Snow Survey Data – *Jones*
- NADP Data - *Jones*
- Tree Band Data – *McGuire and Ruess*
- Tree Inventory Data – *McGuire and Ruess*
- Litter Tray Data – *McGuire and Ruess*
- Vegetation Composition Data – *T. Hollingsworth*
- Seed Tray Data – *Johnstone*
- Animal Population Data – *Werner (insects) and Kielland (mammals)*

Bonanza Creek White spruce ANPP

FP4A – mature white spruce floodplain site
UP3A – mature white spruce upland site

Methods

ANPP derived from band dendrometers using established allometric relationships and presented as gC/tree/year.

Data were scaled to stand level using inventory data, and presented here as gC/ha/yr.

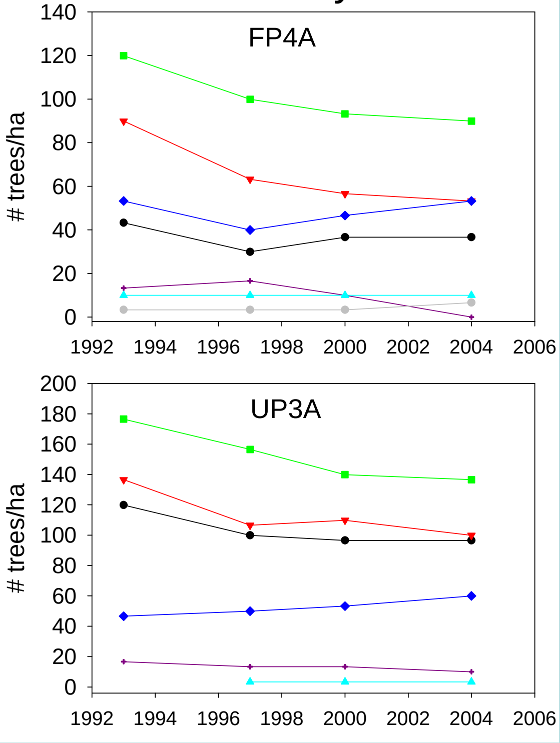
DBH Classes (cm)

class0 = 0 – 9.9
class1 = 10 - 19.9
class2 = 20 – 29.9
class3 = 30 – 39.9
class4 = 40 – 49.9
class5 = 50 – 59.9
class6 = 60 – 69.9

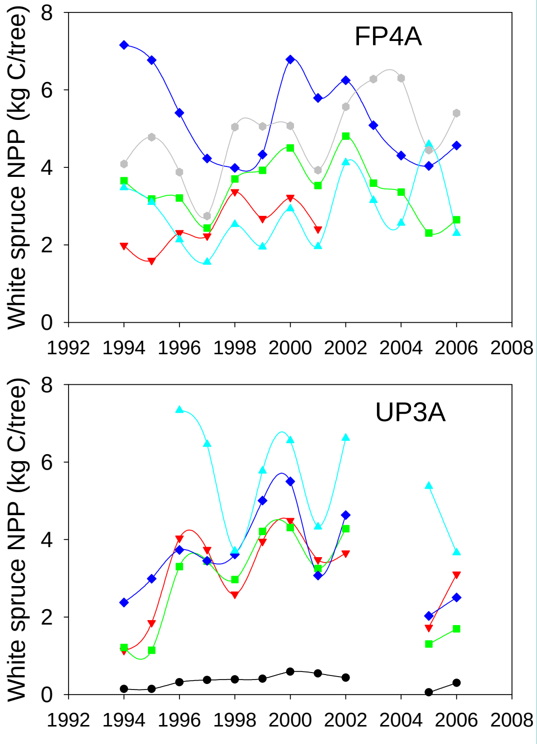
NOTES:
UP3A doesn’t include trees from size class 0.
FP4A doesn’t include trees from size class0 and class1.
This is because there was no band dendrometer data for trees from these size classes.

White spruce aboveground NPP

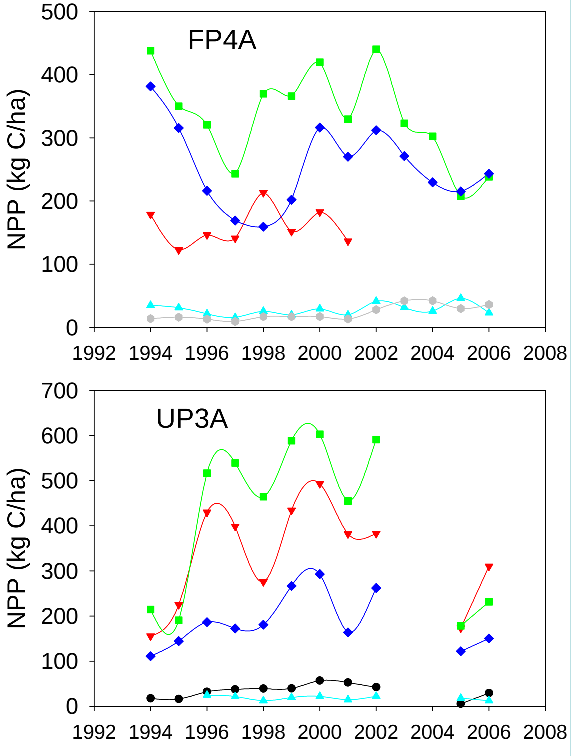
Inventory Data



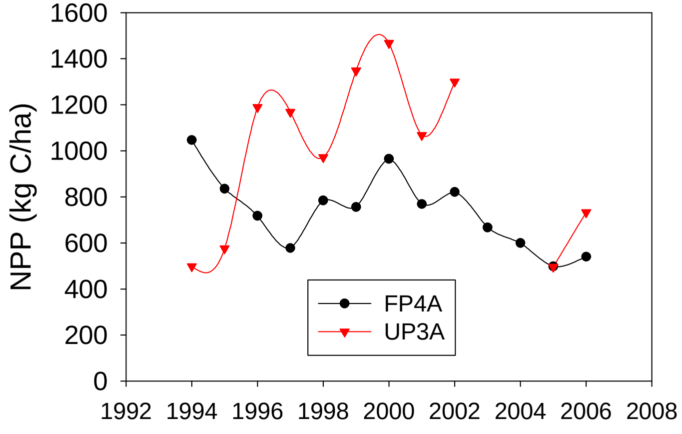
Band Dendrometer Data

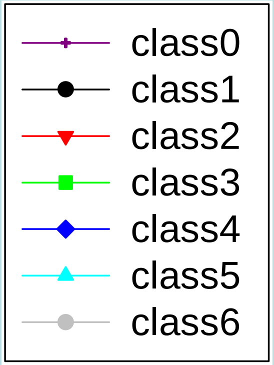


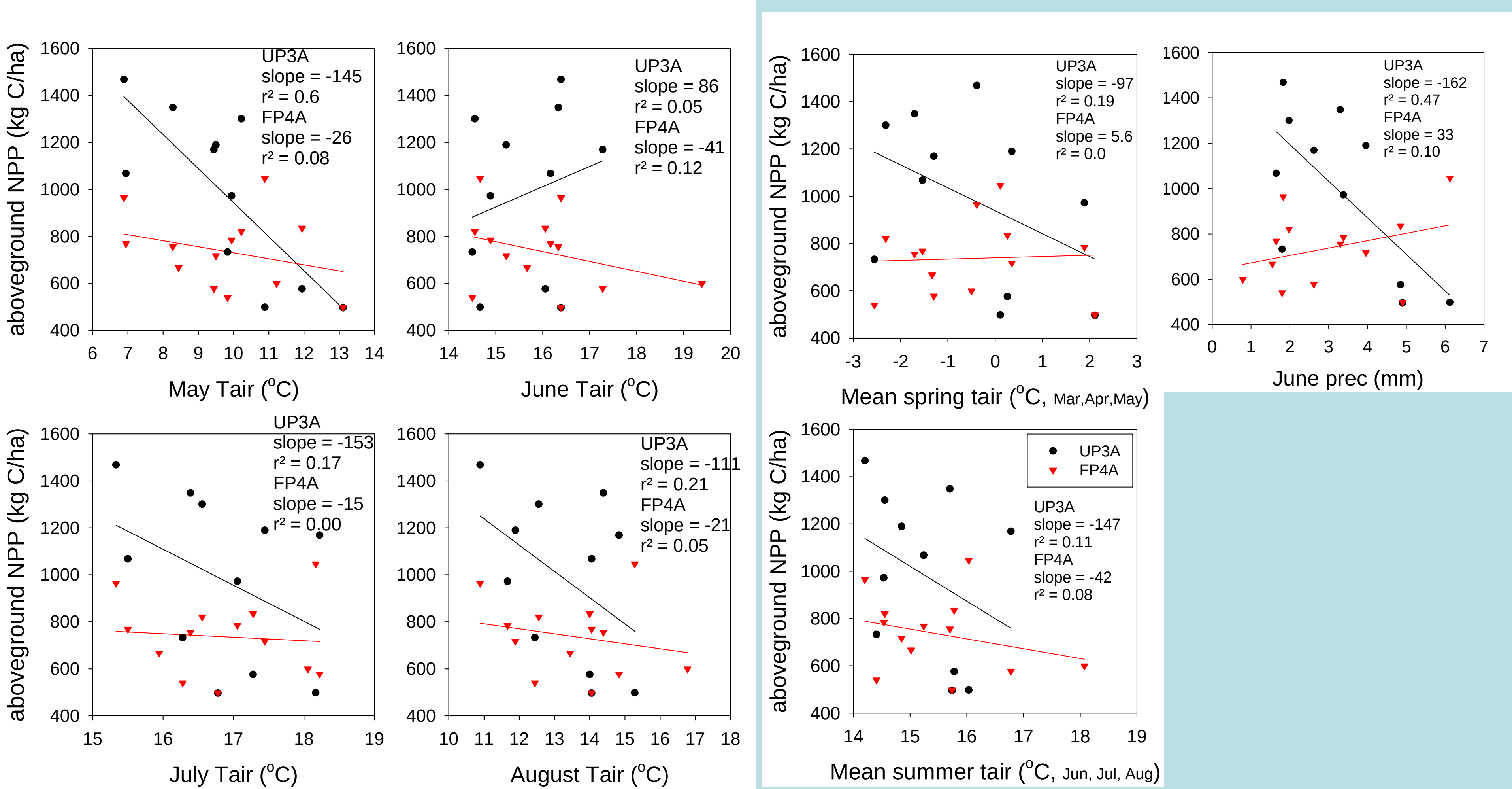
NPP Data by size class



NPP Data for each Site






aboveground NPP (kg C/ha)
400
600
800
1000
1200
1400
1600
UP3A
slope = -145
r² = 0.6
FP4A
slope = -26
r² = 0.08
6
7
8
9
10
11
12
13
14
May Tair (°C)
UP3A
slope = 86
r² = 0.05
FP4A
slope = -41
r² = 0.12
14
15
16
17
18
19
20
June Tair (°C)
aboveground NPP (kg C/ha)
UP3A
slope = -97
r² = 0.19
FP4A
slope = 5.6
r² = 0.0
-3
-2
-1
0
1
2
3
Mean spring tair (°C, Mar,Apr,May)
UP3A
slope = -162
r² = 0.47
FP4A
slope = 33
r² = 0.10
0
1
2
3
4
5
6
7
June prec (mm)
aboveground NPP (kg C/ha)
UP3A
slope = -153
r² = 0.17
FP4A
slope = -15
r² = 0.00
15
16
17
18
19
July Tair (°C)
UP3A
slope = -111
r² = 0.21
FP4A
slope = -21
r² = 0.05
10
11
12
13
14
15
16
17
18
August Tair (°C)
aboveground NPP (kg C/ha)
● UP3A
▼ FP4A
UP3A
slope = -147
r² = 0.11
FP4A
slope = -42
r² = 0.08
14
15
16
17
18
19
Mean summer tair (°C, Jun, Jul, Aug)

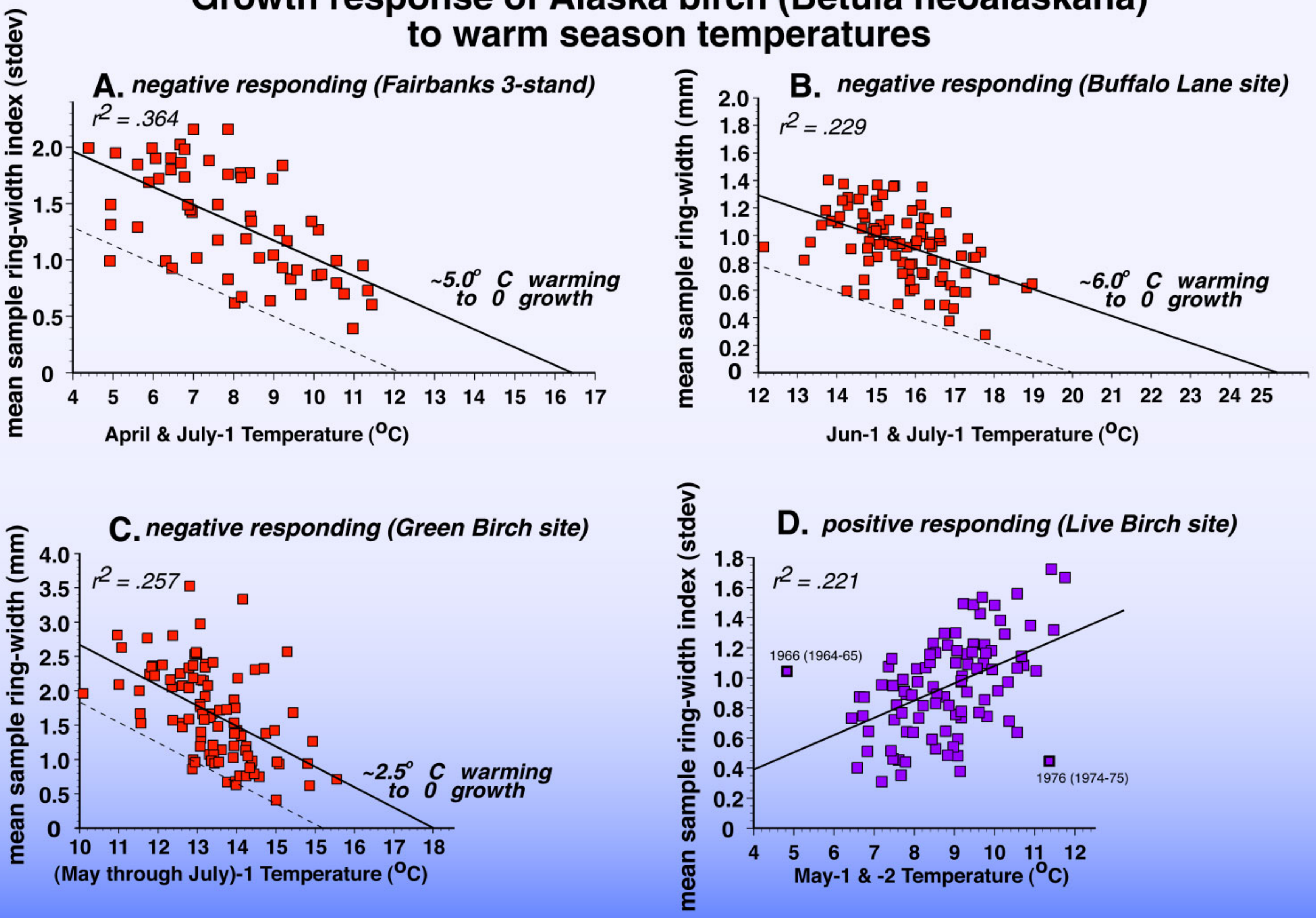
Status

- There is substantial interannual variation in white spruce ANPP at both tree and stand levels over a decade.
- It appears that ANPP can be partially explained by climate variability.
- Overall, warm/drier weather decreased ANPP, with the UPLAND trees/stand more sensitive than the FLOODPLAIN trees/stand.
- We are continuing with this analysis across the range of BNZ LTER monitoring sites.

Climate Sensitivity Research Tasks

C2 - ***Use tree-ring analysis to assess the sensitivity of tree-ring width to climatic variation*****. (Juday, Lloyd)**

Growth response of Alaska birch (Betula neoalaskana) to warm season temperatures

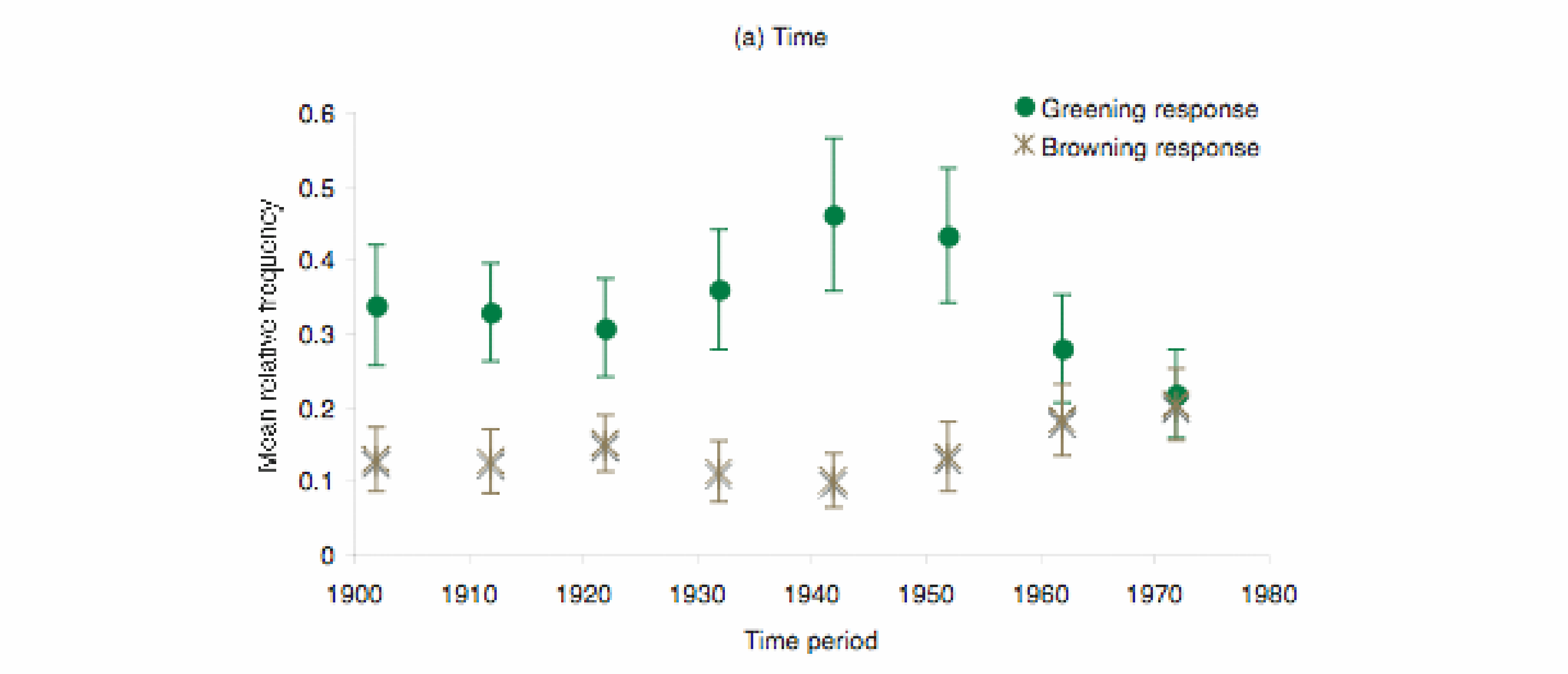


Glenn Juday

C2. Use tree-ring analysis to assess the sensitivity of tree-ring width to climatic variation. (Lloyd)

- Research title: *Responses of the circumpolar boreal forest to historical climate variability.* (Primary funding from NSF grant ARC 06-12346; collaborative with Dr. Andy Bunn, Western Washington University.)
- Key question: *How does tree growth response to climate vary (a) among species, (b) around the circumpolar north, and (c) over time?*
- Approach:
  - Re-analyze existing tree-ring data archived in the International Tree-Ring Data Bank
  - Develop new collections:
    - Under-sampled species (black spruce, aspen, birch)
    - Update older chronologies (esp in Russian collections)
    - Fill geographic gaps (central Canada, parts of Siberia)

Positive growth responses to temperature have become *less* common since the mid-1900s, while negative growth responses to temperature have become *more* common.

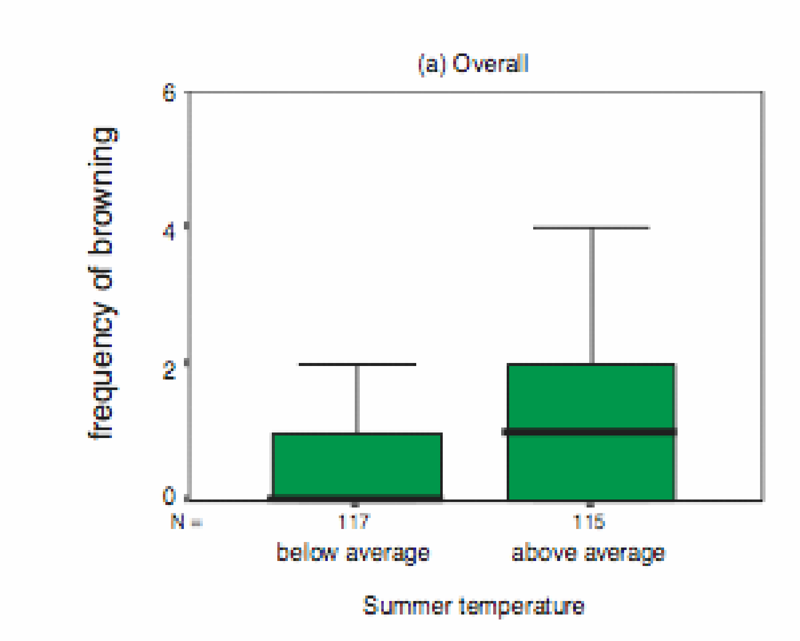


Lloyd & Bunn, In Review, Environmental Research Letters

Negative growth responses to temperature are concentrated in five species, and occur more frequently in sites at the warm end of a species range.

Species with significantly higher rates of inverse growth response to temperature:

- *Picea abies*
- *Picea glauca*
- *Picea mariana*
- *Picea obovata*
- *Pinus banksiana*

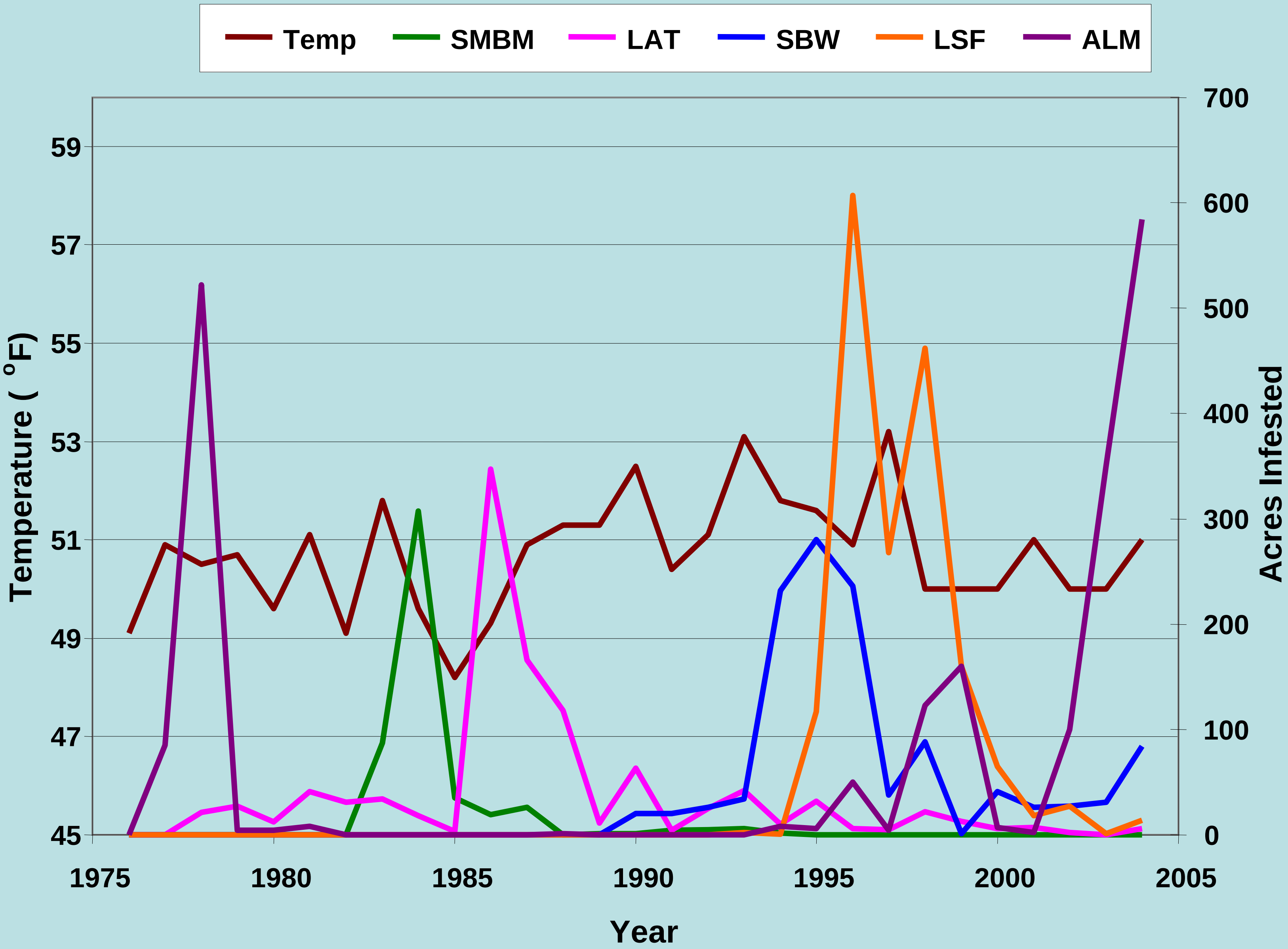


Lloyd & Bunn, In Review, Environmental Research Letters

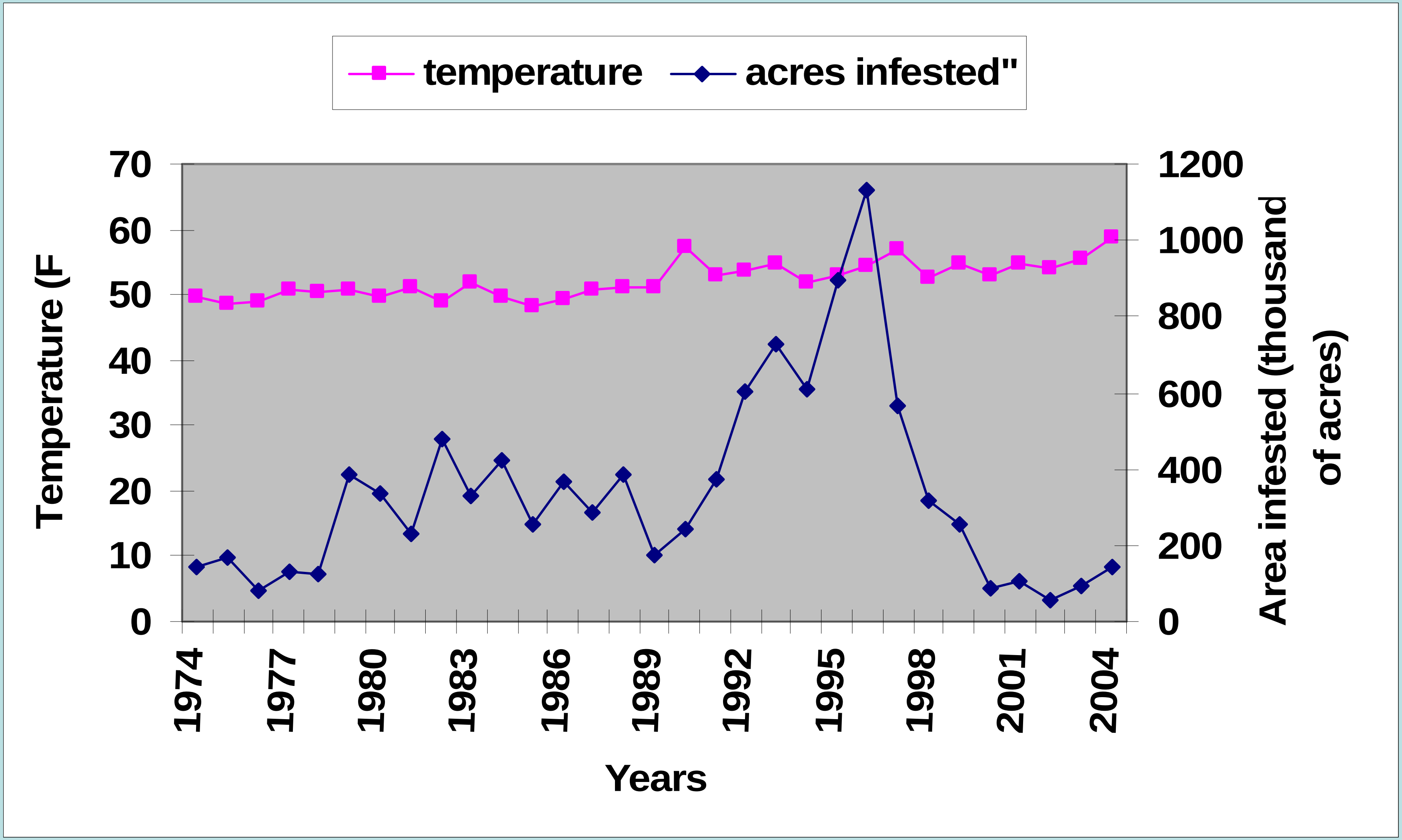
Climate Sensitivity Research Tasks

C3 - ***Document the effects of climate variability, vegetation type, and predation on herbivore abundance*****.** **(Kielland, Werner, Hanley)**

Mean May-August Temperatures and Thousands of Infested Acres



Mean May-August temperatures and acres of spruce ecosystems infested in Alaska



Climate appears to have had a positive impact on population trends of forest insects in Alaska during the 1980s through the mid-1990s

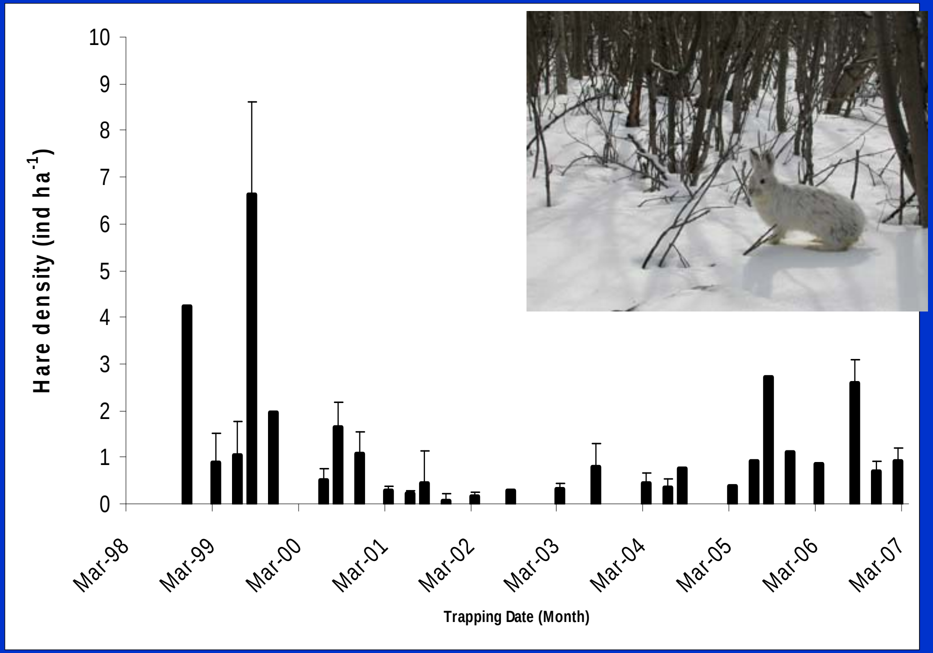
Task C3. Document the effects of climate variability, vegetation and predation on herbivore abundance

Intensive study: ***Snowshoe hares ecology***

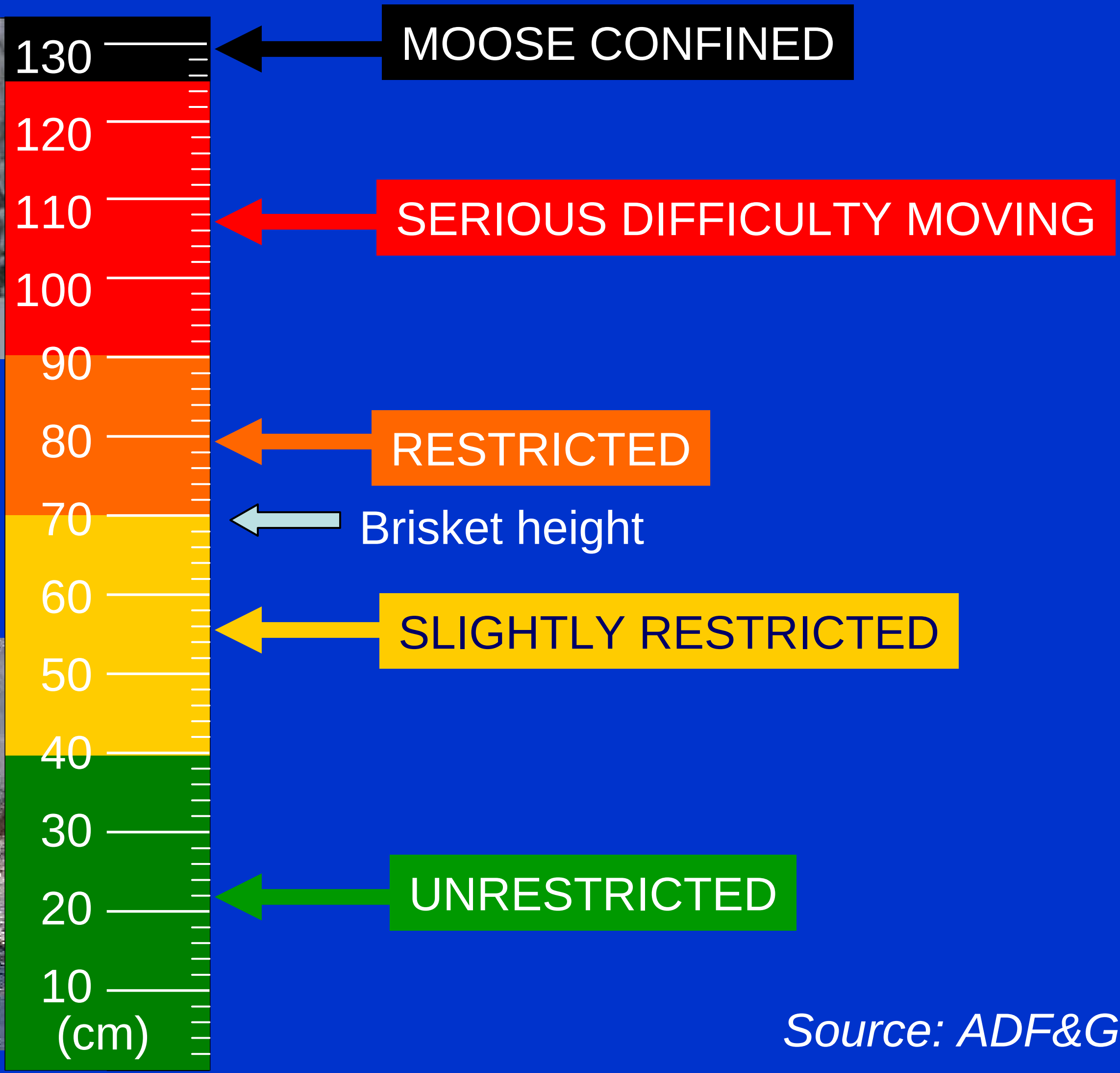
- **Plant-Herbivore interactions**
- **Hare demography**

Extensive study: ***Moose and wolves***

- **Successional dynamics**
- **Moose foraging ecology**



Snow depth affects moose mobility and foraging ecology



MOOSE CONFINED

SERIOUS DIFFICULTY MOVING

RESTRICTED

Brisket height

SLIGHTLY RESTRICTED

UNRESTRICTED

Source: ADF&G

DIRECTIONS:

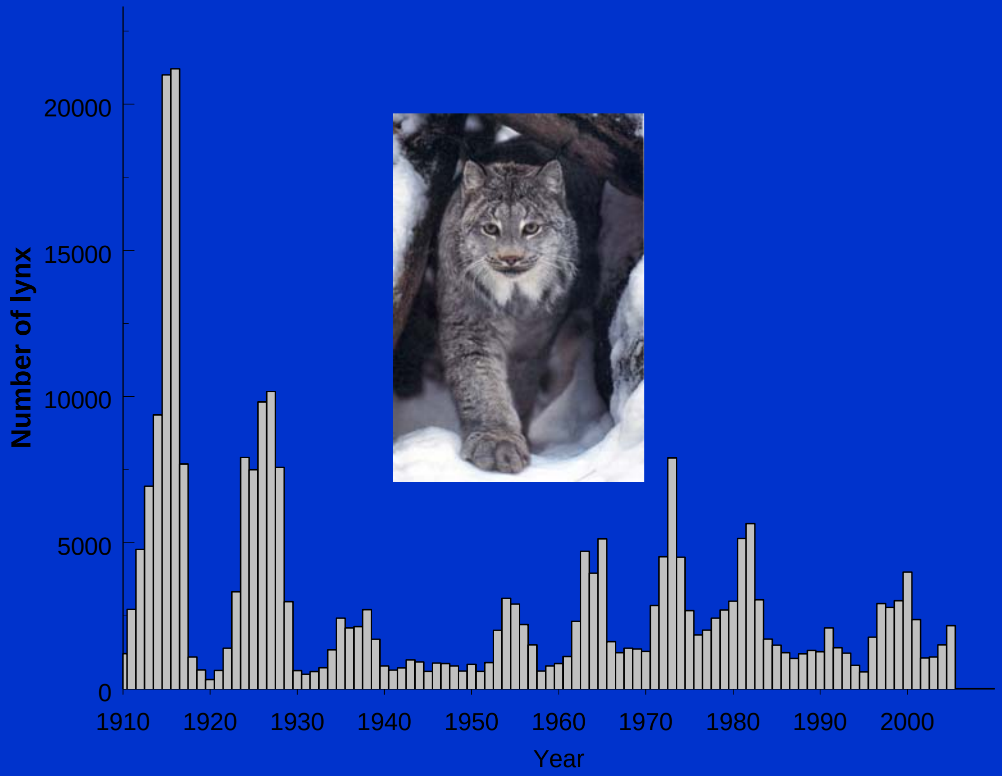
Snowshoe hare ecology:

Augment snowshoe hare studies to include predation, and refine demographic studies using radio tags.

Moose studies:

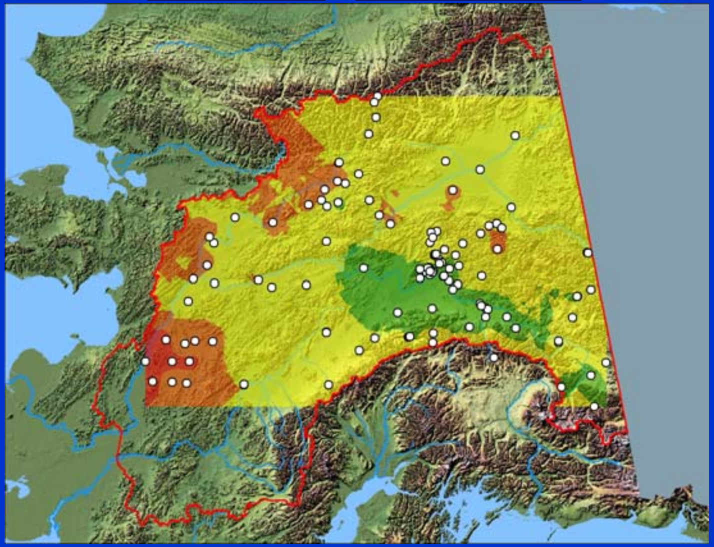
Examine moose vegetation dynamics in low-moose density ecosystems (Yukon River)

Examine snow-forage relationships for moose over large scales in interior Alaska



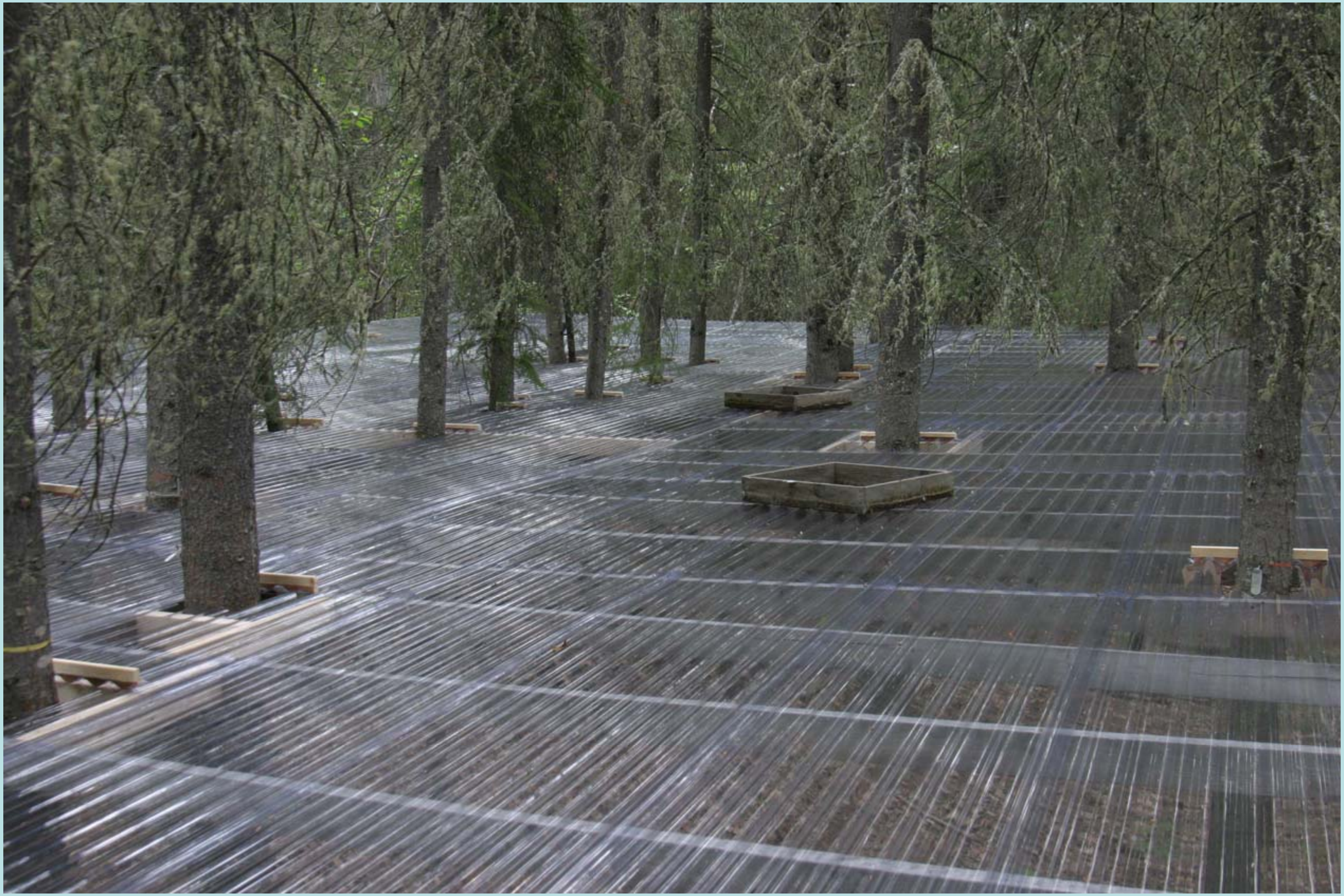
Snow depth 🟥 90-125 cm

🟩 **40 cm** 🟨 **40-70 cm**



Climate Sensitivity Research Tasks

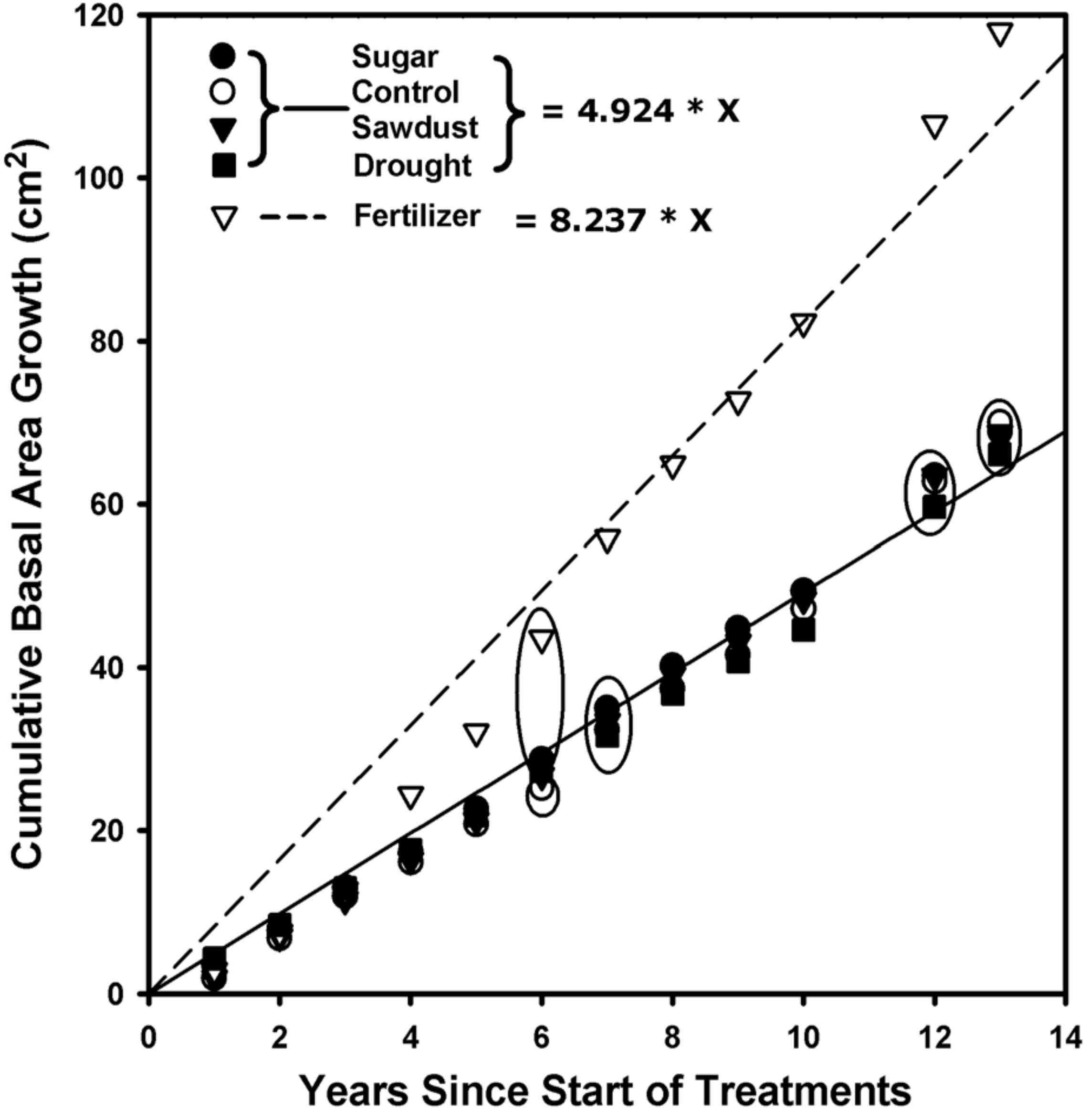
C4 - *Manipulate soil moisture to assess its effects on NPP and other ecosystem processes*. (Yarie, Turetsky, Harden, McGuire, Valentine)

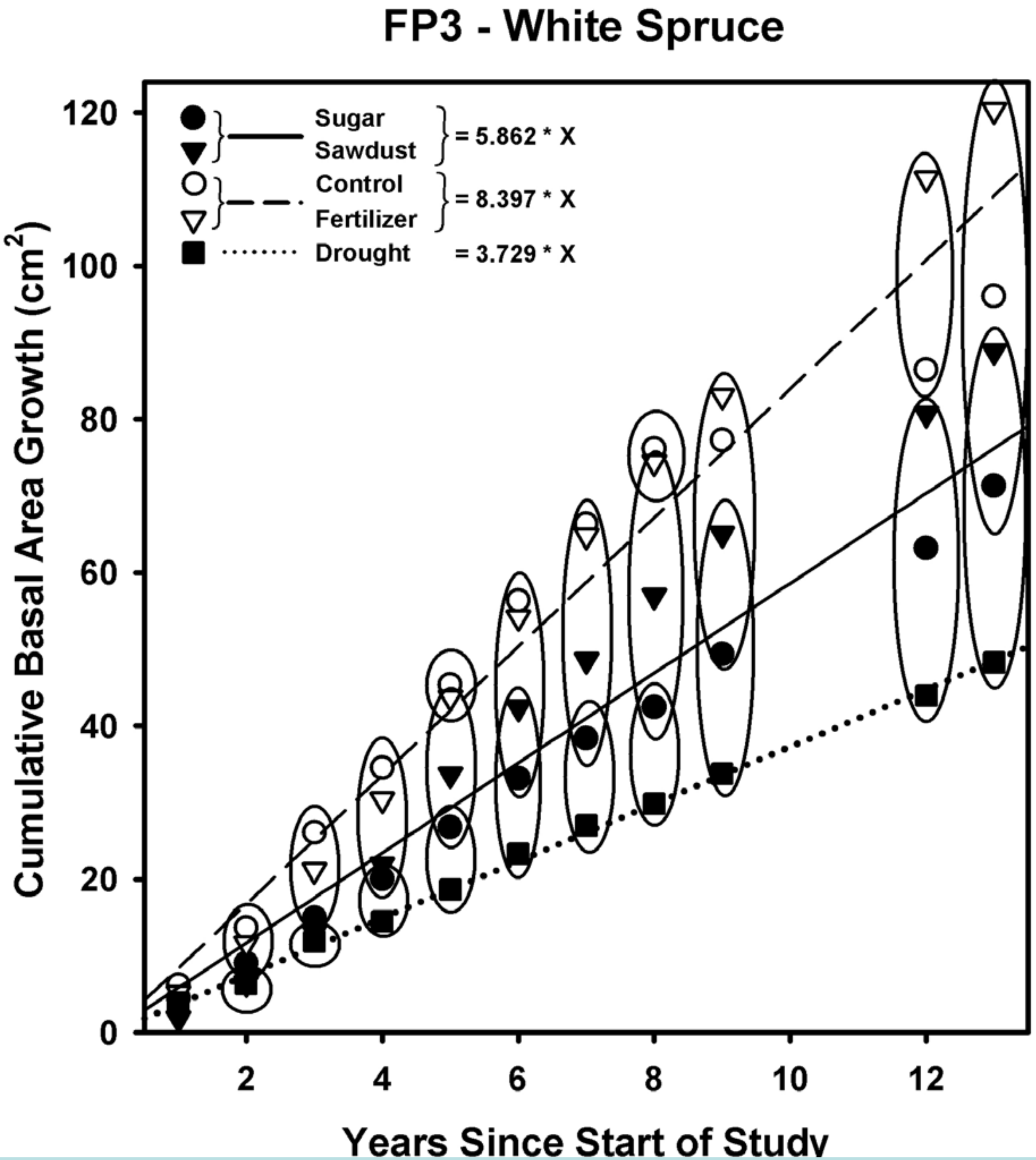


Hypotheses

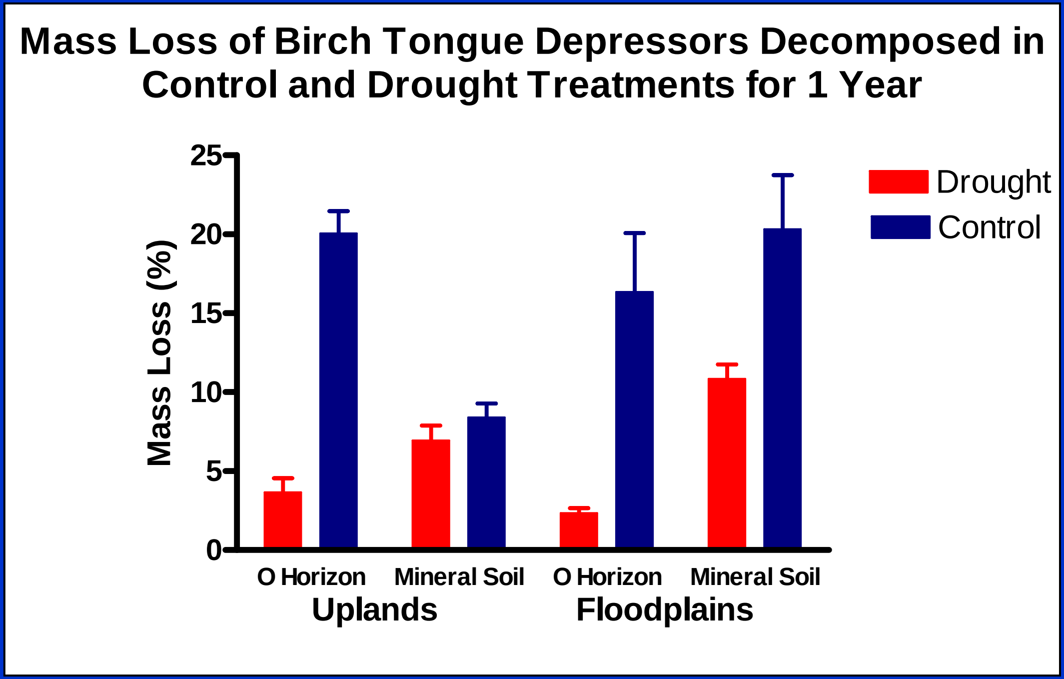
- The initial hypotheses were:
  - (1) forest growth in upland birch/aspen (*Betula neoalaskana* Sarg./ *Populus tremuloides* Michx.) stands is strongly controlled by summer rainfall, and
  - (2) forest growth in balsam poplar/white spruce (*Populus balsamifera L.*/ *Picea glauca* (Moench) Voss) ecosystems on the floodplain will show no relationship to summer rainfall due to the influence of ground water, related to river flow dynamics, on soil moisture recharge.

UP2 - White Spruce




FP3 - White Spruce
Cumulative Basal Area Growth (cm²)
0
20
40
60
80
100
120
2
4
6
8
10
12
Years Since Start of Study
● ▼ Sugar Sawdust = 5.862 * X
○ ▽ Control Fertilizer = 8.397 * X
■ Drought = 3.729 * X

Standard Substrate Decomposition

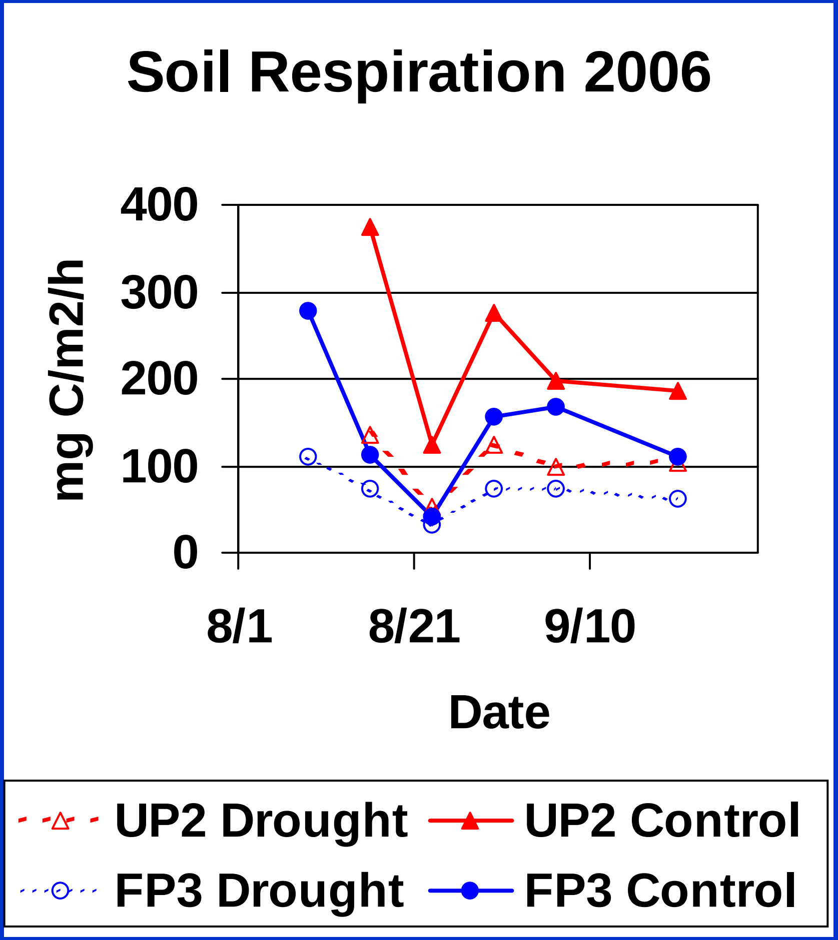


- **O horizon**: Drought reduced decomposition of birch tongue depressors (BTDs) by more than 80% in both upland ($p = .001$, $n = 3$) and floodplain ($p = .03$, $n = 3$) sites

- **0-15 cm mineral soil**: Drought did not significantly reduce BTD decomposition in upland ($p = .064$, $n = 3$) or floodplain ($p = .077$, $n = 3$) sites

Runck, Valentine, and Yarie

Soil Respiration in 2006



- Consistent with Billings et al. (1998), drought continues to reduce soil CO_2 efflux in both upland (UP2, 55%) and floodplain (FP3, 45%) sites at rates similar to 1996.
- Apportion Rs into Rh and Ra using several techniques

Valentine, Yarie, Runck

Future Studies

- Hypotheses:
  - Snowmelt will significantly reduce upland growth
  - Snowmelt will have no significant effect of floodplain tree growth
- Experiment design
  - Allow summer rainfall
  - Eliminate fall rainfall and spring snowmelt recharge of soil water
- Quantify drought impact on soil C budget
  - Determine total belowground C allocation
  - Separate Rs into Ra & Rh

Task C4: manipulate soil moisture and its effects on NPP and other ecosystem properties

www.apex.msu.edu

Overall question: How does peat temperature and water table position control vegetation and carbon cycling processes?

Research approach: Factorial design of water table manipulations (soil flooding and drying) and soil warming.

Upland to Wetland Gradient

MSU
Bonanza LTER
NSF CZEN, NSF Ecosystems

Dry

Wet

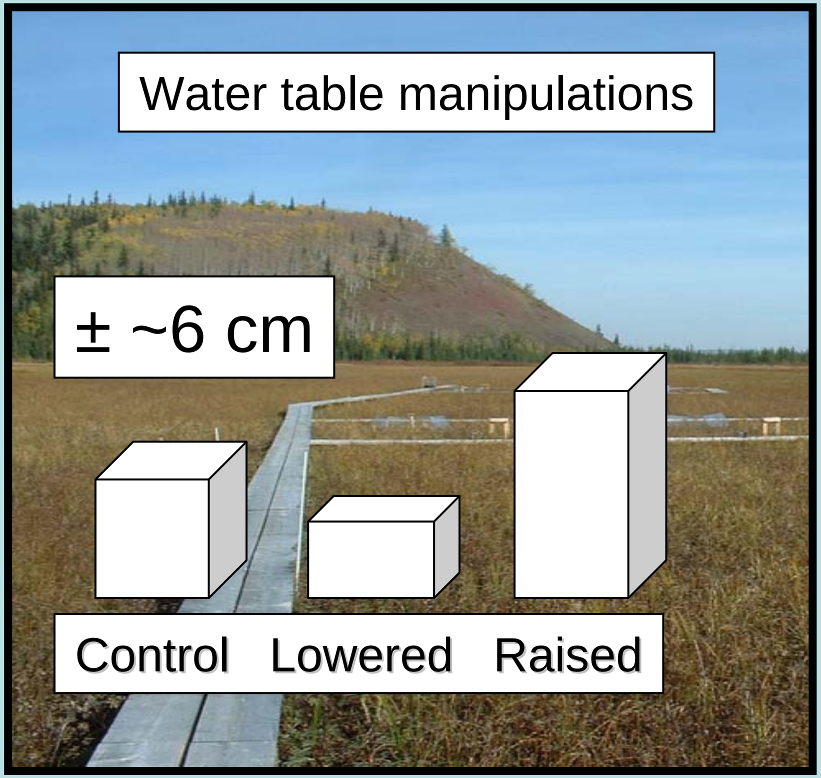
Black Spruce

Willow/Bog Birch

Tussock Grass

Equisitum Carex

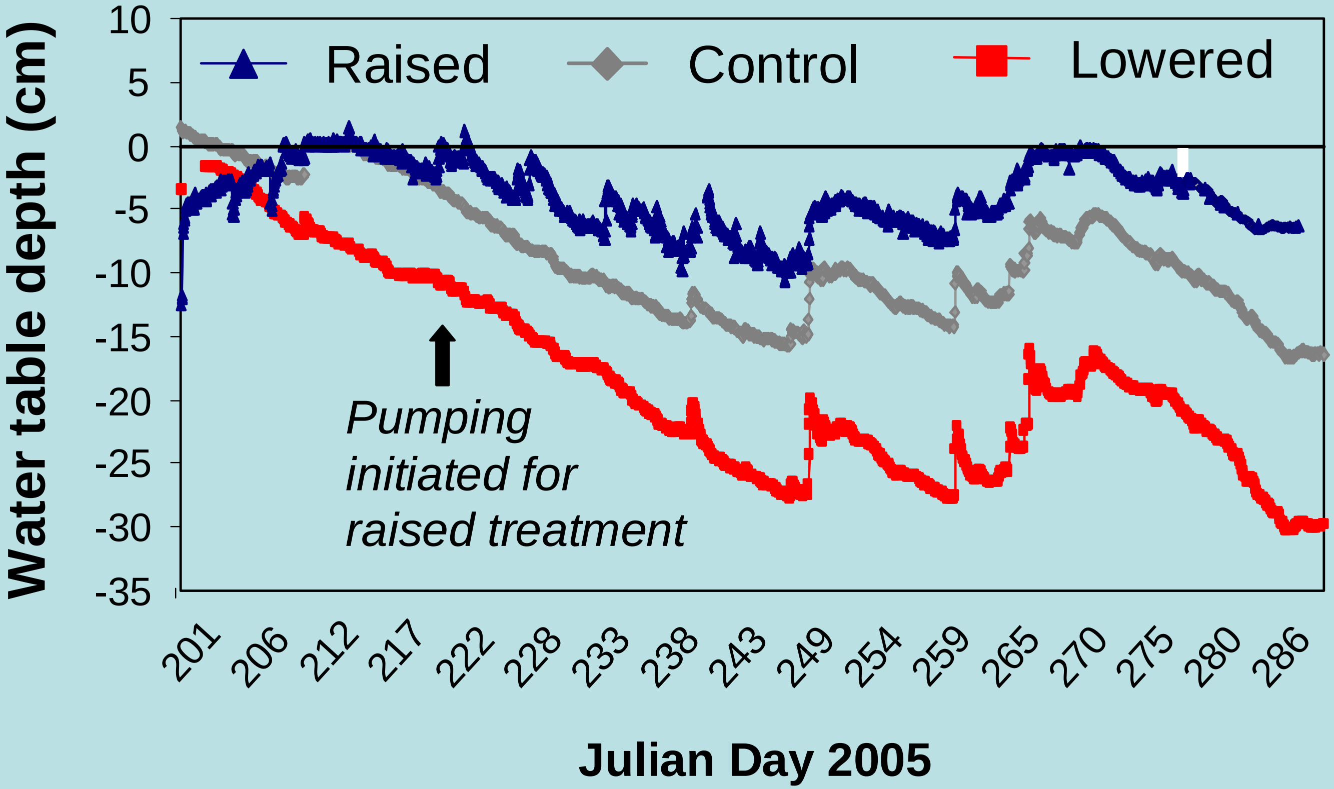
Drapanacladus



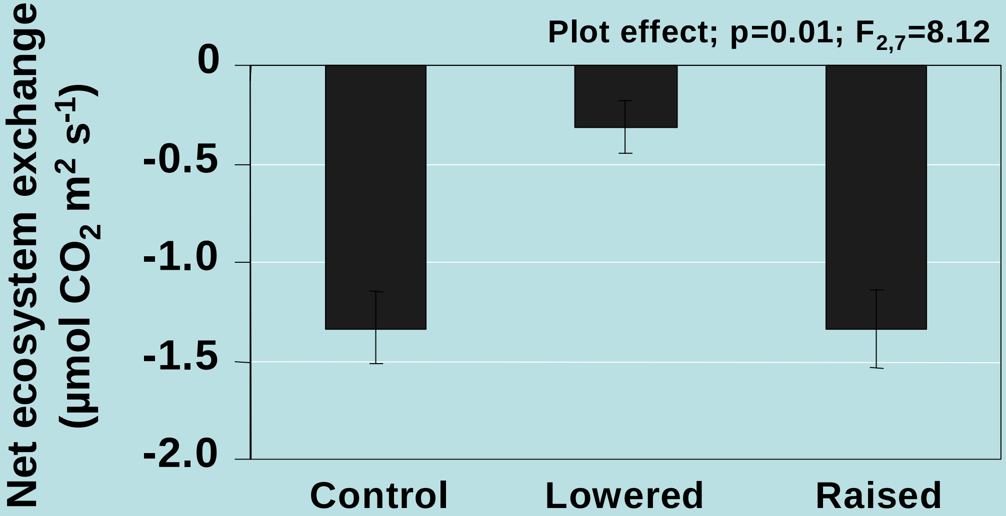
Water table manipulations

± ~6 cm

Control Lowered Raised



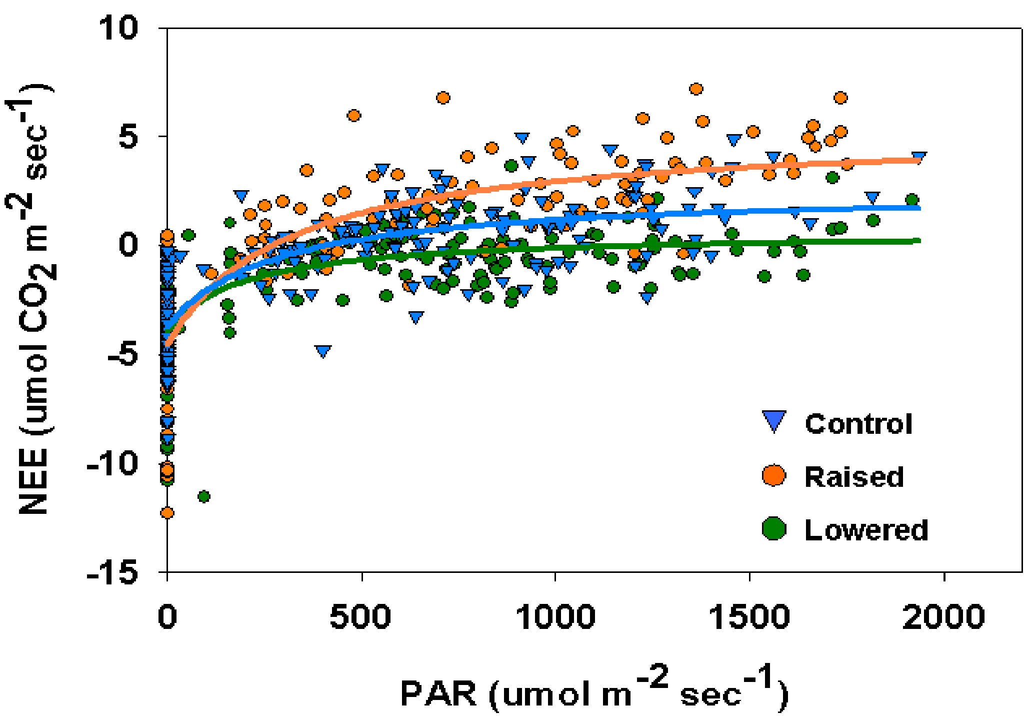
Pumping initiated for raised treatment



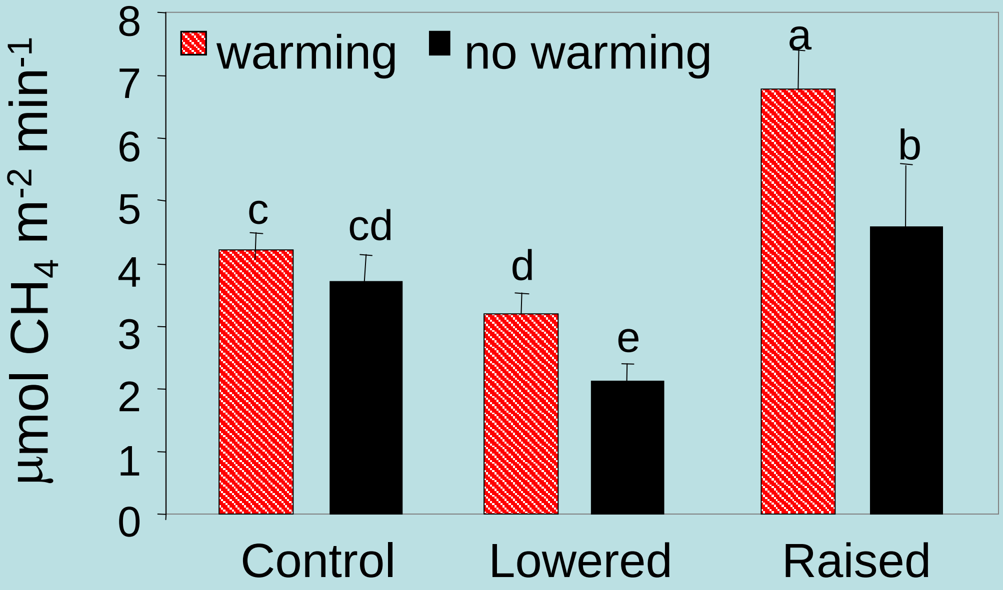
CO_2 Fluxes

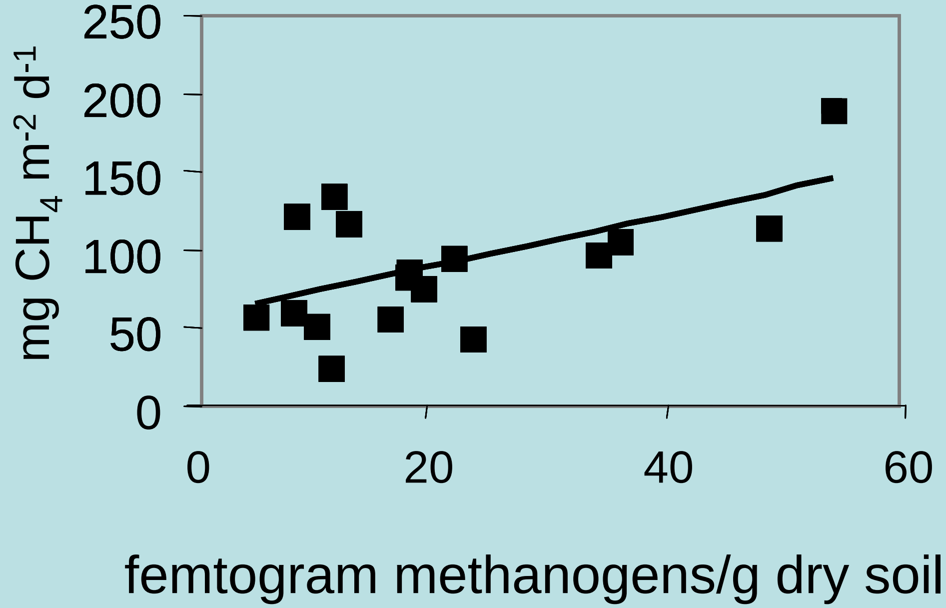
- Net ecosystem exchange (NEE) varied across water table treatments, with lower NEE in the lowered (drought) plot.

Light response curves show that vegetation in the raised (flooded) and control plots fix more C per unit of PAR than plants in the lowered plot



Conlin et al. in prep





CH_4 Fluxes

- CH_4 fluxes varied by a water table x soil warming interaction

Daily mean water table position and 25 cm peat temperature explained ~ 70% of the variation in CH_4 fluxes across our plots

Methanogen abundance responded to our experimental treatments, and was positively related to CH_4 fluxes

Treat et al. in review, JGR Biogeosciences

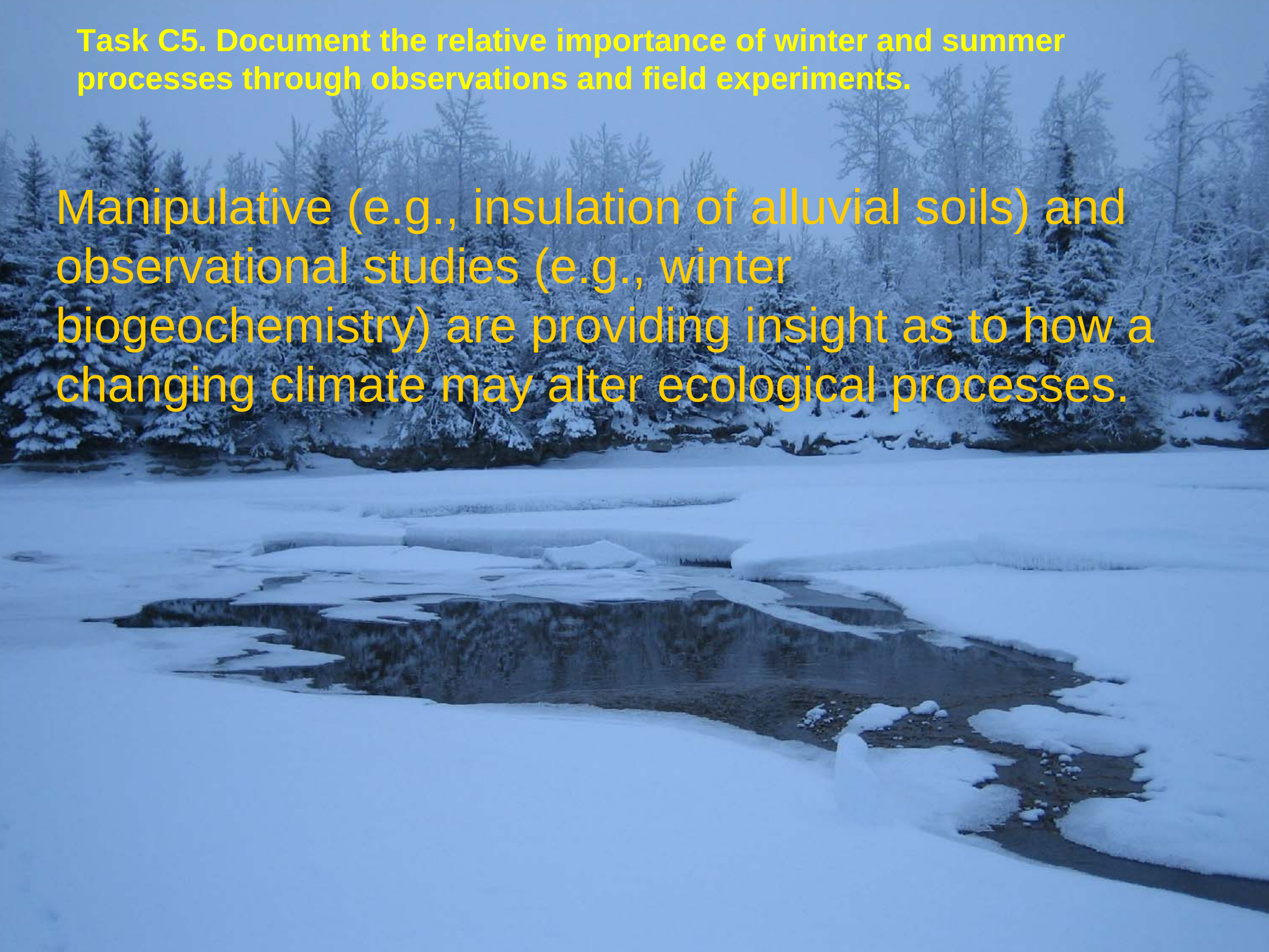
C fluxes responded quickly to our experimental treatments, with water table position serving as strong controls on both CO_2 and CH_4 fluxes.

In 2007, NSF made an award to expand this design into two additional sites. Future research also will focus on 1) changes in soil C and N mineralization rates under altered soil climate regimes, 2) effects of snowpack depth on ecosystem structure and function, and 3) hydrologic connections at both site and catchment scales.

The site includes several transitional communities situated at the interface between forests and floodplain LTER sites, and offers the opportunity to model the fate and transport of C at the catchment scale.

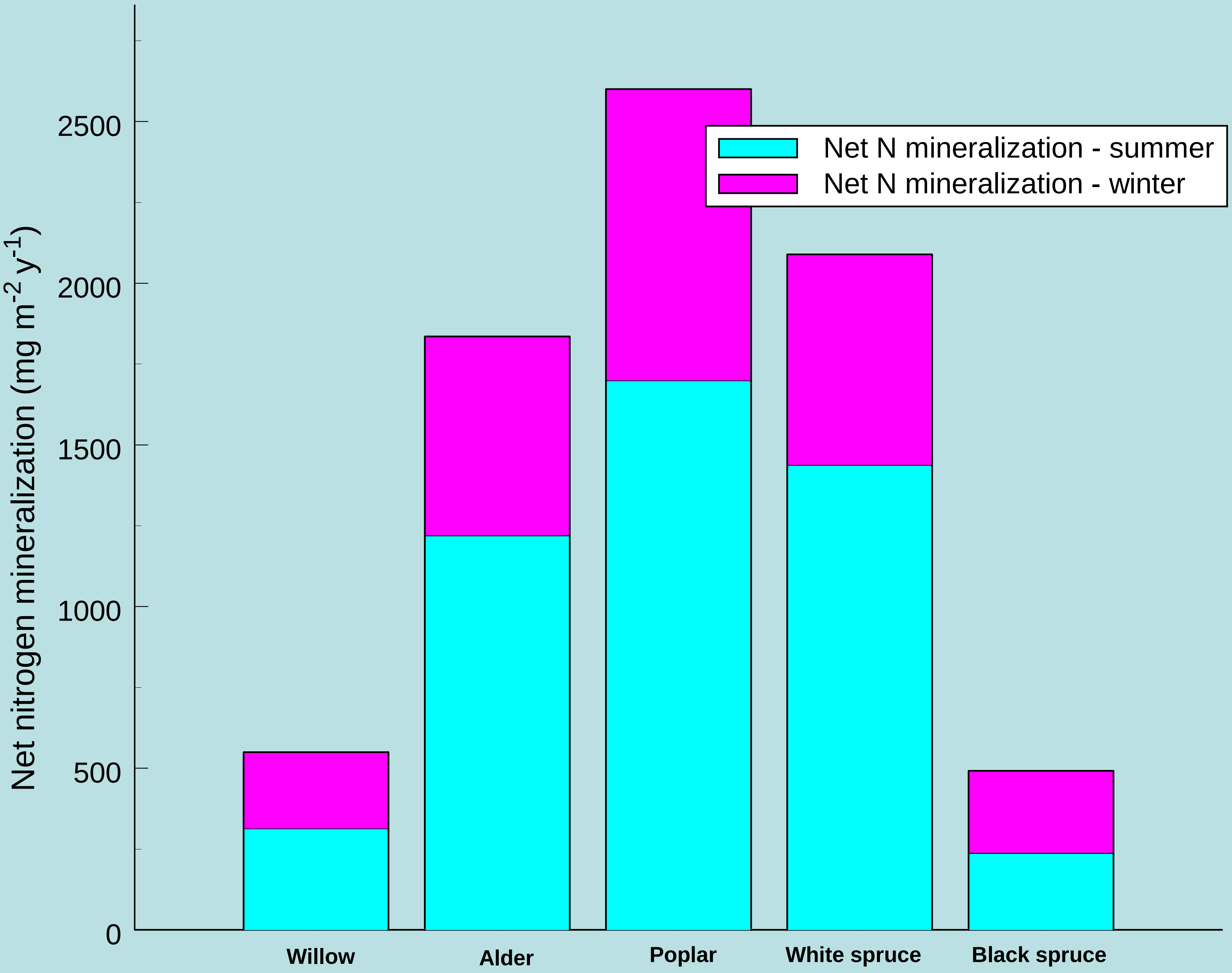
Climate Sensitivity Research Tasks

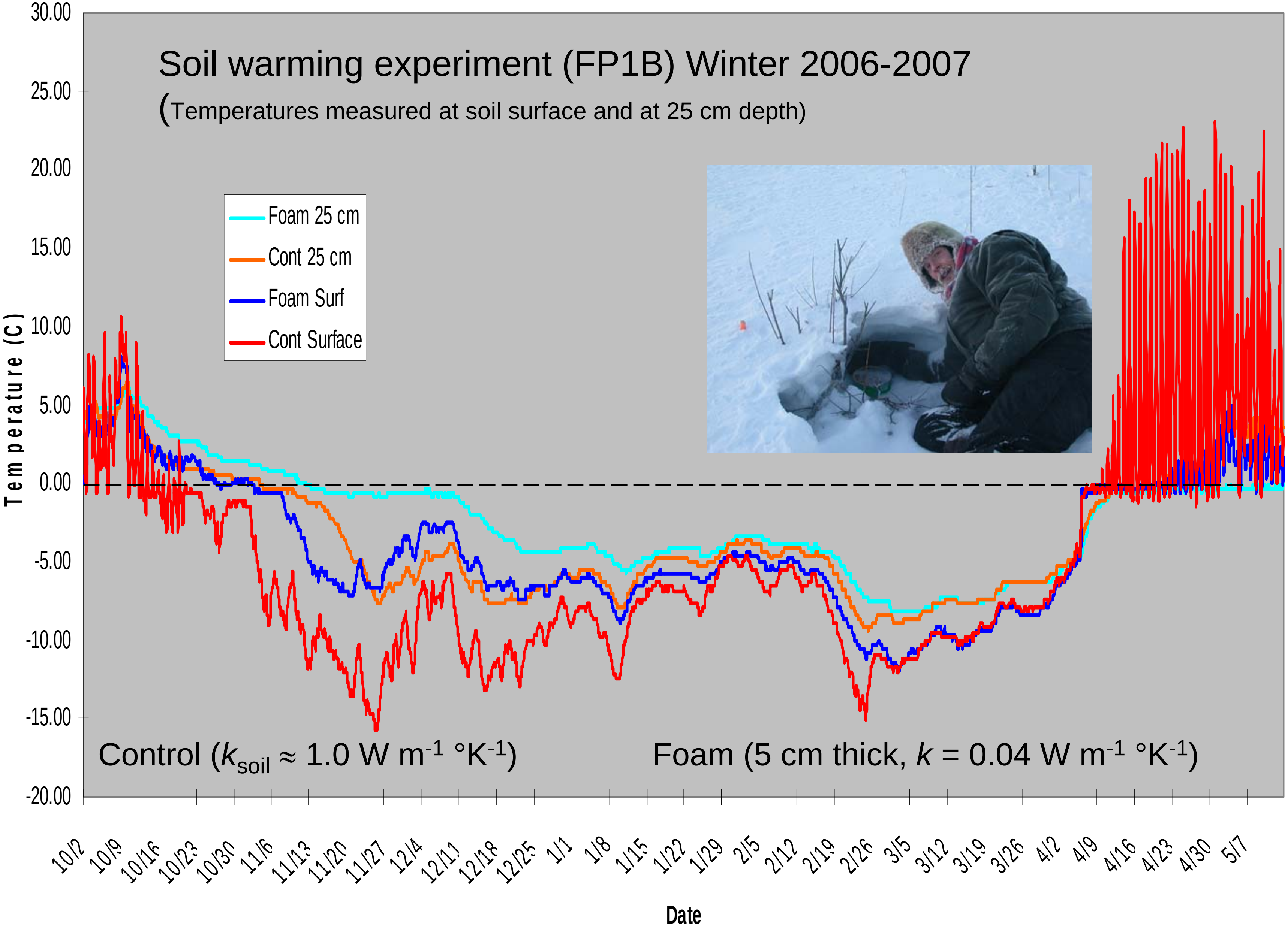
C5 - ***Document the relative importance of winter and summer processes through observations and field experiments*****. (Kielland, Turetsky, Harden, McGuire)**



Task C5. Document the relative importance of winter and summer processes through observations and field experiments.

Manipulative (e.g., insulation of alluvial soils) and observational studies (e.g., winter biogeochemistry) are providing insight as to how a changing climate may alter ecological processes.


Net nitrogen mineralization (mg m-2 y-1)
0
500
1000
1500
2000
2500
Net N mineralization - summer
Net N mineralization - winter
Willow
Alder
Poplar
White spruce
Black spruce

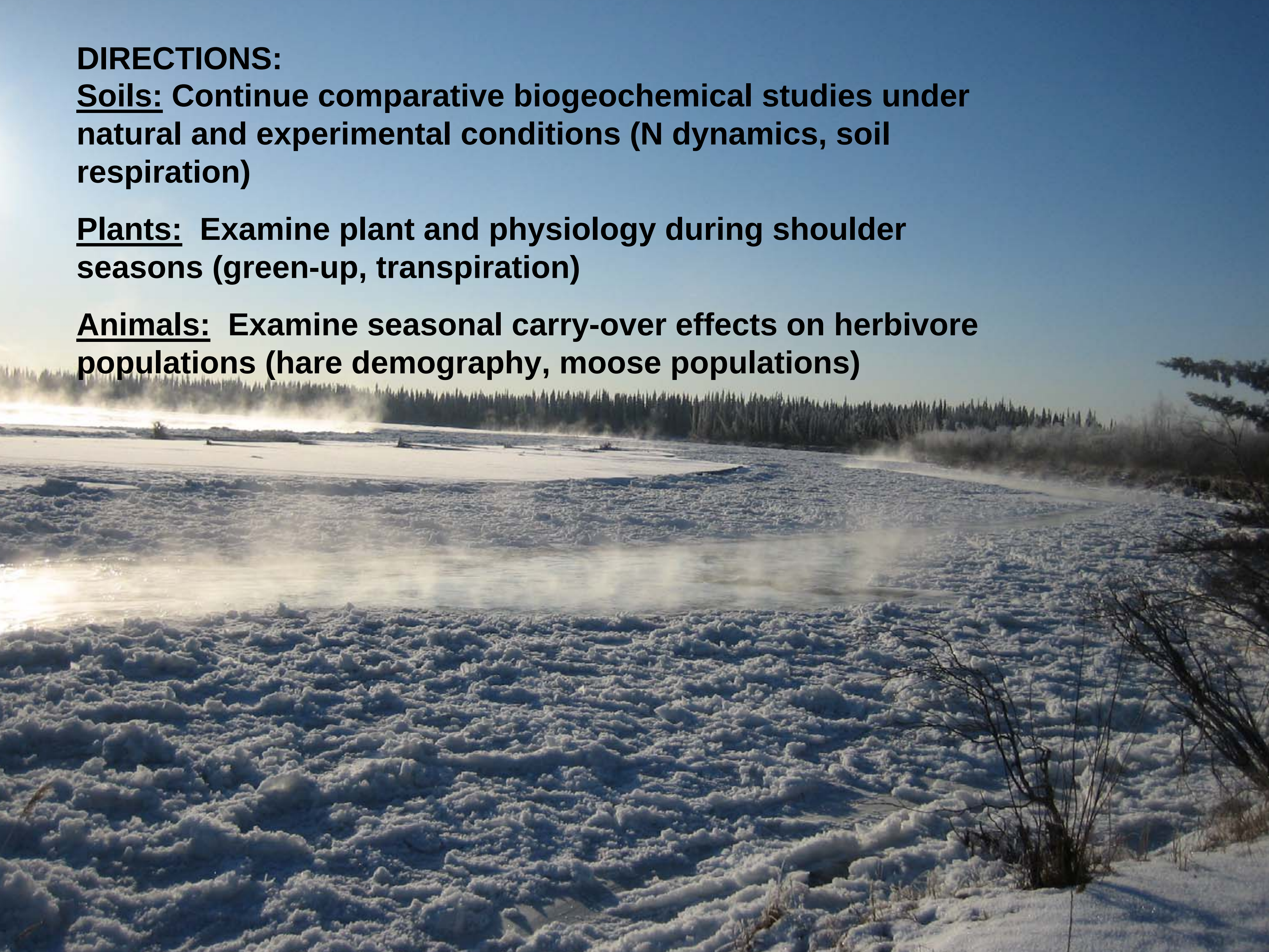


Soil warming experiment (FP1B) Winter 2006-2007

(Temperatures measured at soil surface and at 25 cm depth)

Control ($k_{soil} \approx 1.0$ W m^{-1} °K^{-1})

Foam (5 cm thick, $k = 0.04$ W m^{-1} °K^{-1})



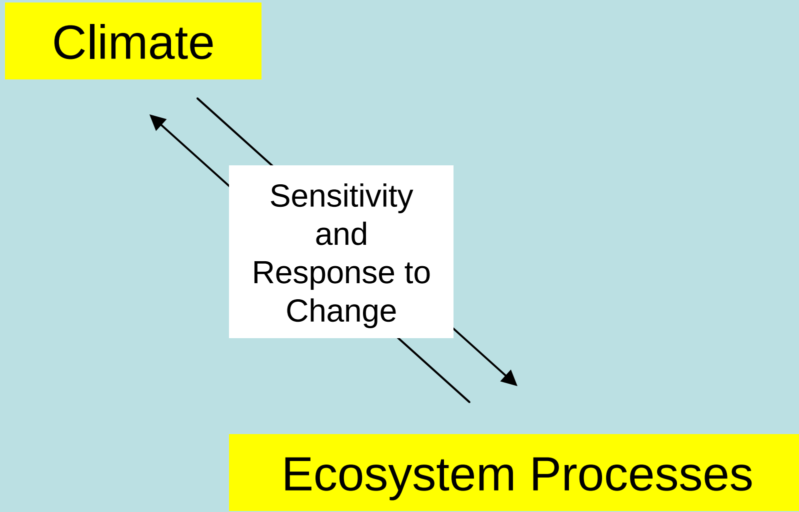
DIRECTIONS:

Soils: Continue comparative biogeochemical studies under natural and experimental conditions (N dynamics, soil respiration)

Plants: Examine plant and physiology during shoulder seasons (green-up, transpiration)

Animals: Examine seasonal carry-over effects on herbivore populations (hare demography, moose populations)

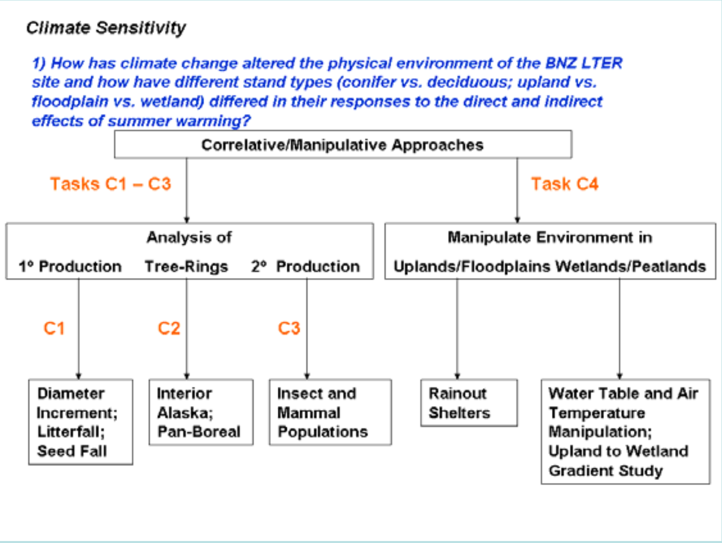
Climate Sensitivity



Climate

Sensitivity and Response to Change

Ecosystem Processes



Climate Sensitivity

1) How has climate change altered the physical environment of the BNZ LTER site and how have different stand types (conifer vs. deciduous; upland vs. floodplain vs. wetland) differed in their responses to the direct and indirect effects of summer warming?

Correlative/Manipulative Approaches

Tasks C1 – C3

Analysis of

1° Production Tree-Rings 2° Production

C1

Diameter Increment; Litterfall; Seed Fall

C2

Interior Alaska; Pan-Boreal

C3

Insect and Mammal Populations

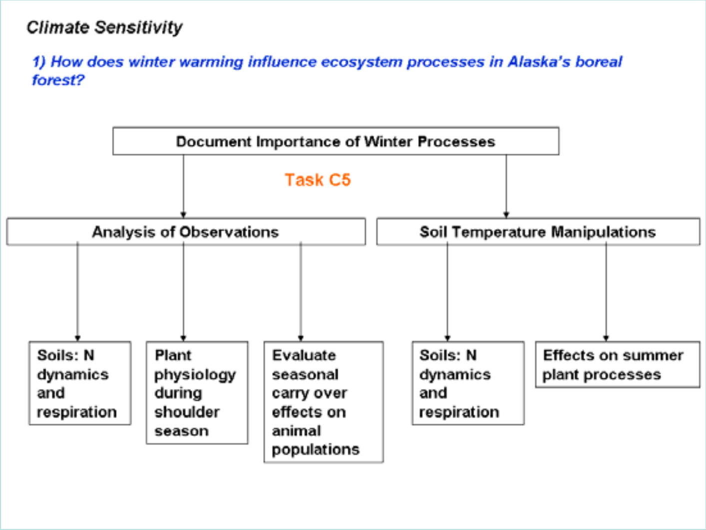
Task C4

Manipulate Environment in

Uplands/Floodplains Wetlands/Peatlands

Rainout Shelters

Water Table and Air Temperature Manipulation; Upland to Wetland Gradient Study



Climate Sensitivity

1) How does winter warming influence ecosystem processes in Alaska's boreal forest?

Document Importance of Winter Processes

Task C5

Analysis of Observations

Soils: N dynamics and respiration

Plant physiology during shoulder season

Evaluate seasonal carry over effects on animal populations

Soil Temperature Manipulations

Soils: N dynamics and respiration

Effects on summer plant processes