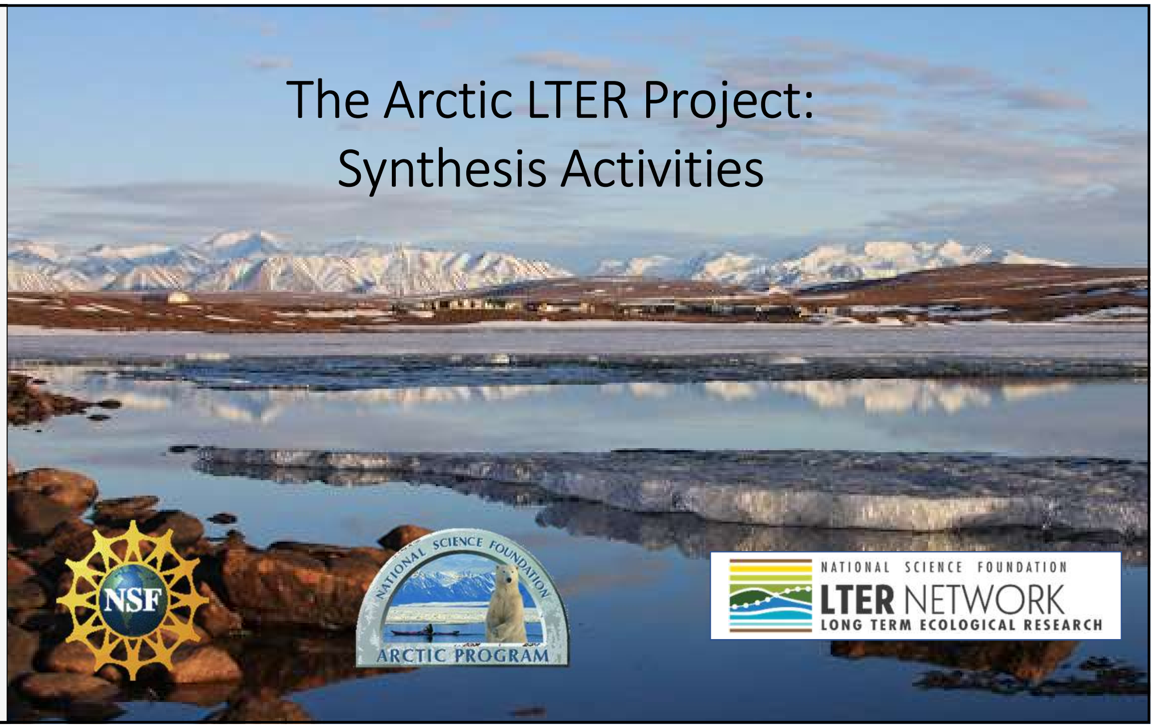
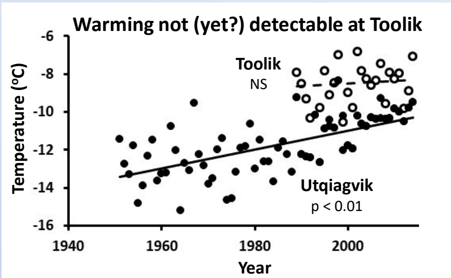
Arctic LTER Project

The Arctic LTER Project: Synthesis Activities

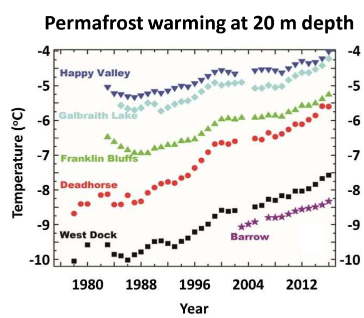


Within-site Synthesis: Long term trends and consequences of warming

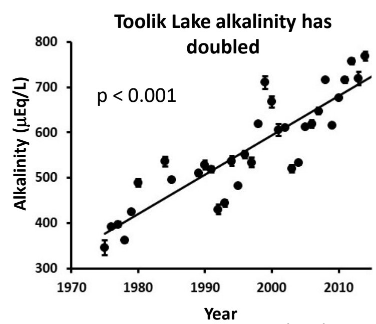


Alaska Climate Research Center (2015)

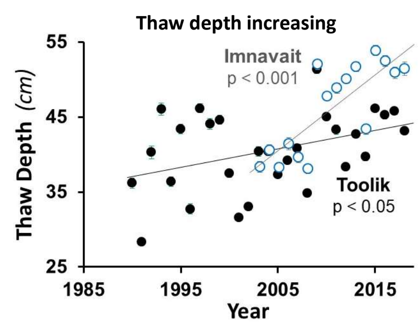
Although air temperature at Toolik Lake has not warmed significantly in the last 40 years, there are other indicators of significant warming (Hobbie et al. 2017).



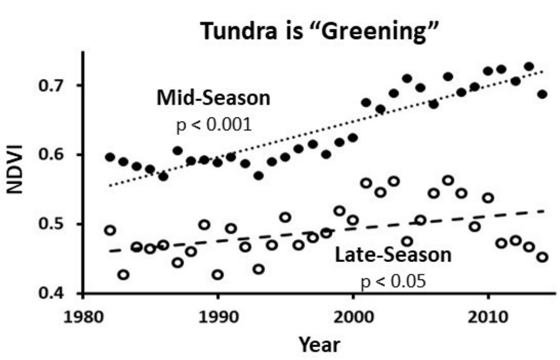
Updated from Romanovsky et al. (2011)



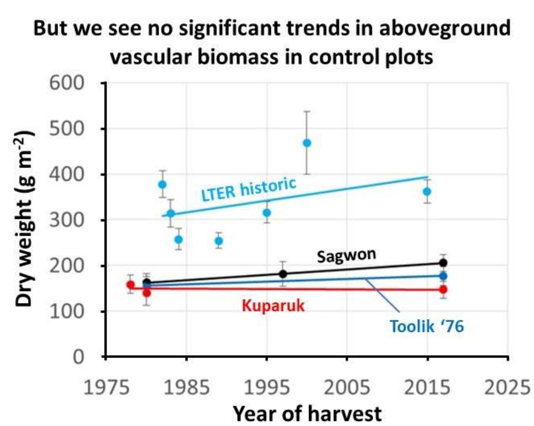
Updated from Kling et al. (2014)



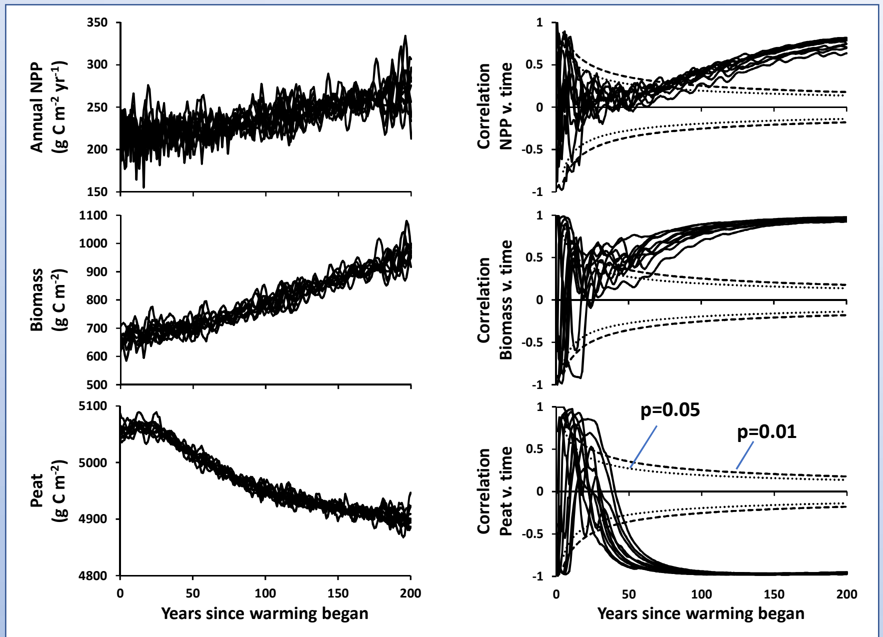
Updated from Hobbie et al. 2017



Data from Guay and Goetz



Data from Shaver



How soon should warming be detected in tundra?

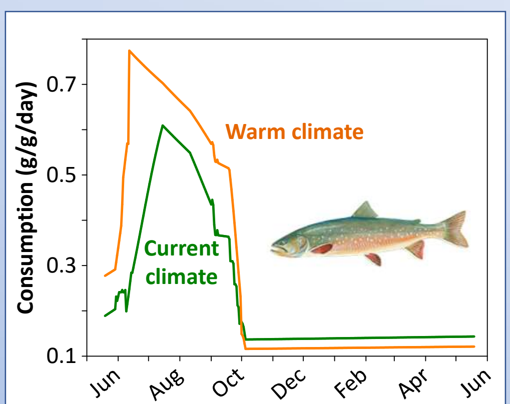
Ten replicate simulations using the MEL model with the same 0.05 °C/yr warming trend but random variation in annual temperature around that trend.

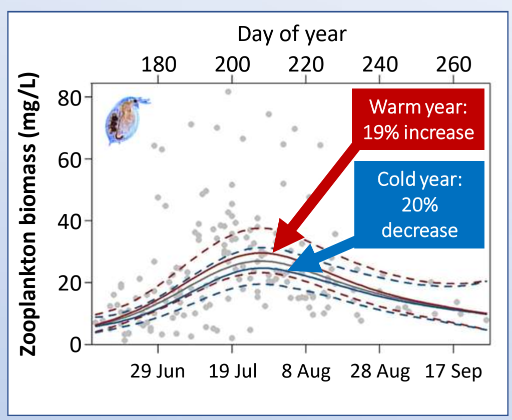
Trend not likely to emerge as significant for 50-100 years even with model's zero measurement error.

Rastetter et al. submitted (special issue of EcoSphere with 4 other LTER network papers)

Critical question for ectotherms: will there be enough food to support increased demand in a warmer climate?

- **consumption demand by fish predicted to increase 28-34 % in a warmer lake**
- **a warmer climate *might* be able to support *some* increased fish demand**





$$Log(Biomass_{ik}) = \alpha + \beta_1 + s(Day\ of\ Year_i) + Temperature_j + a_k + \varepsilon_{ik}$$

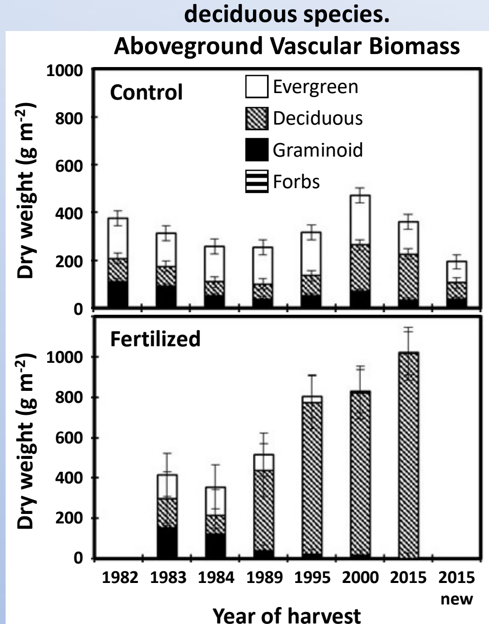
Budy and Luecke 2014

Klobucar et al. 2018

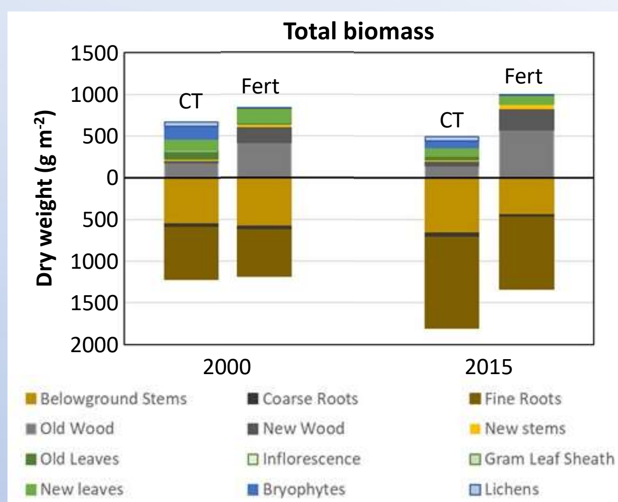
Within-site Synthesis: Fertilization experiments in terrestrial, stream, and lake ecosystems

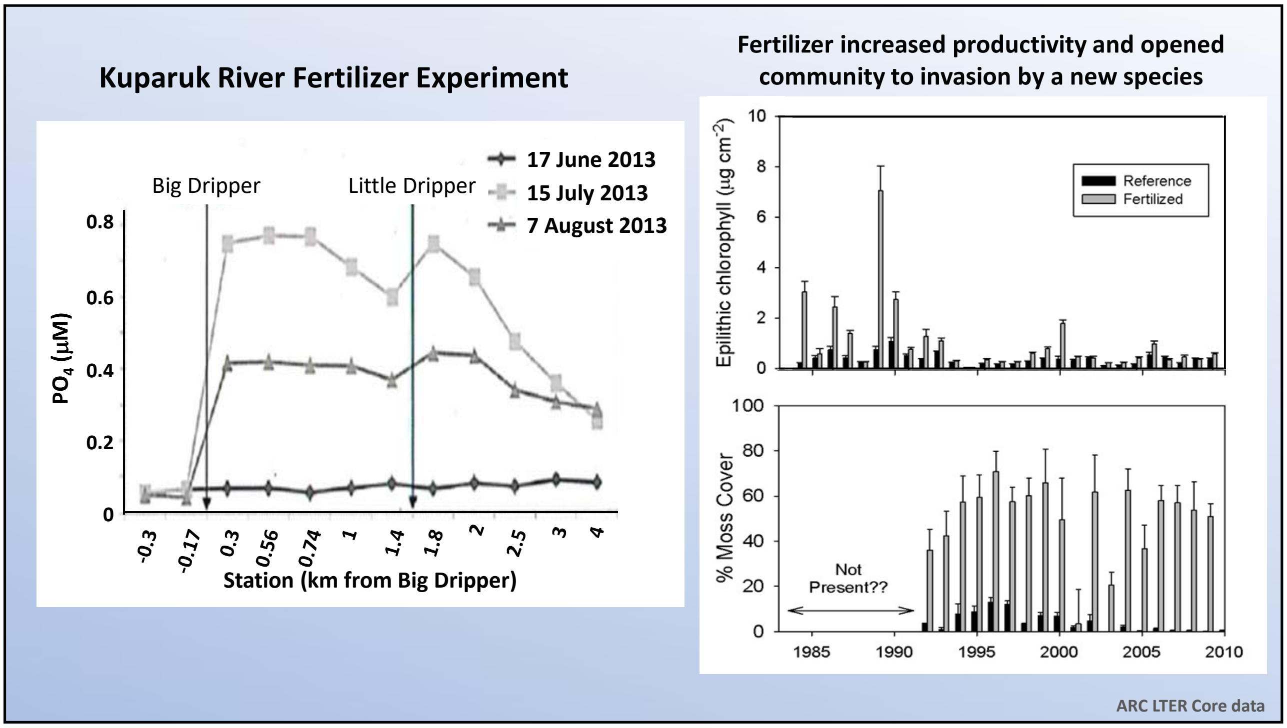
Warming should stimulate microbial activity and thaw organic matter currently frozen in permafrost resulting in an increase in nutrient availability across the arctic landscape

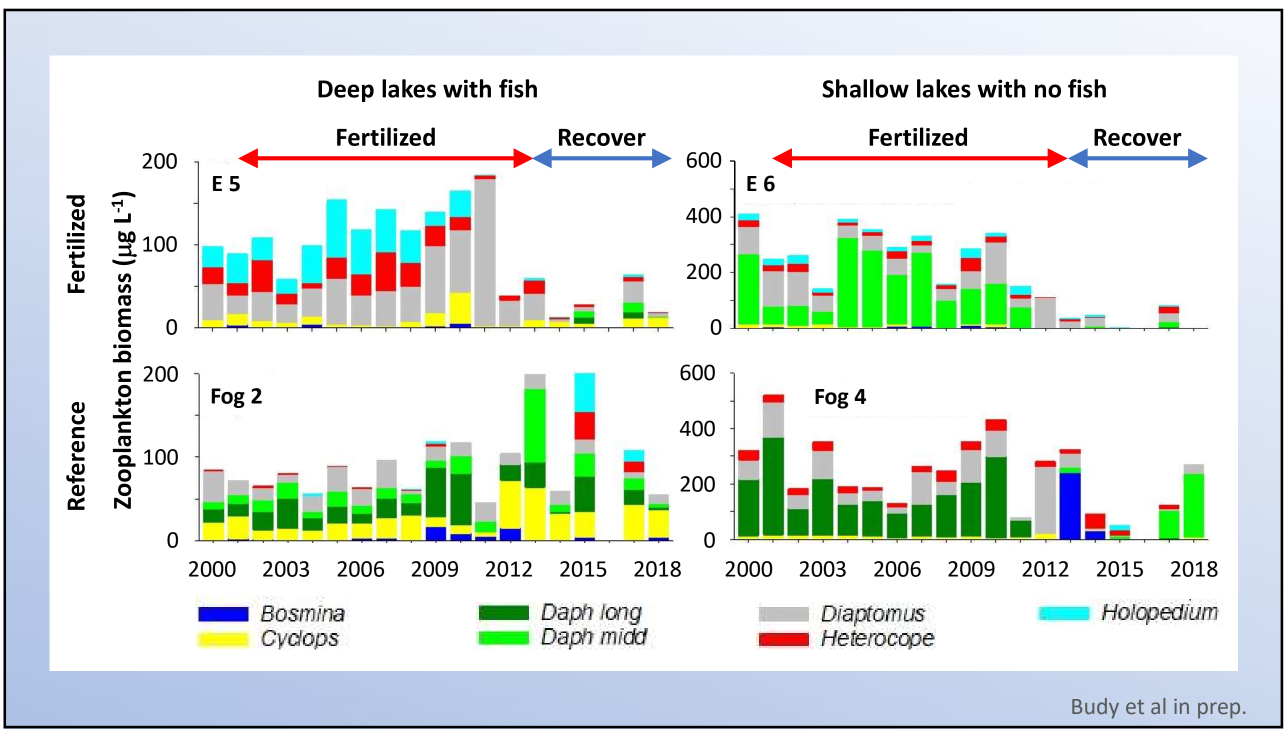
Increased fertility favors woody deciduous species.



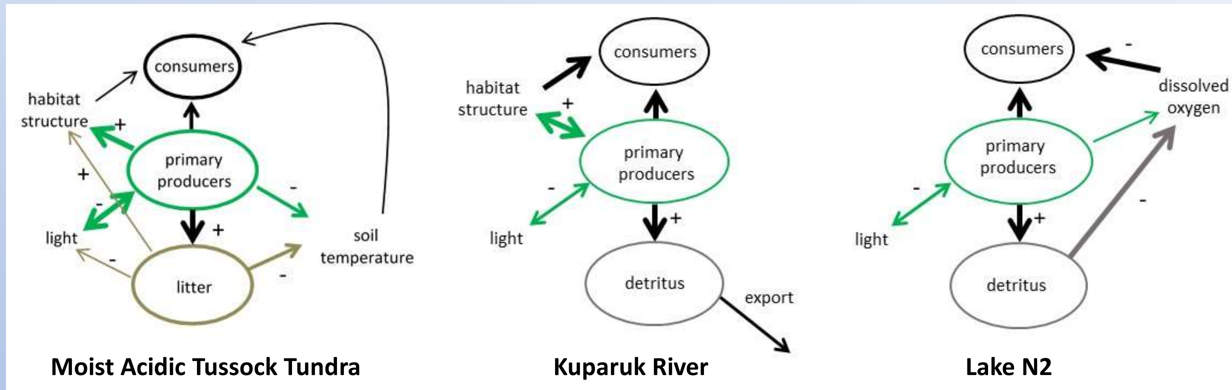
However, gains in aboveground biomass are offset by decreases in belowground biomass when bryophytes & lichens are included.




Kuparuk River Fertilizer Experiment
Big Dripper
Little Dripper
17 June 2013
15 July 2013
7 August 2013
PO4 (µM)
0.8
0.6
0.4
0.2
0
-0.3
-0.17
0.3
0.56
0.74
1
1.4
1.8
2
2.5
3
4
Station (km from Big Dripper)
Fertilizer increased productivity and opened community to invasion by a new species
Epilithic chlorophyll (µg cm-2)
Reference
Fertilized
% Moss Cover
Not Present??
1985
1990
1995
2000
2005
2010
ARC LTER Core data


Deep lakes with fish
Shallow lakes with no fish
Fertilized
Recover
Fertilized
Recover
E 5
E 6
Fog 2
Fog 4
Fertilized
Reference
Zooplankton biomass (µg L-1)
2000
2003
2006
2009
2012
2015
2018
Bosmina
Cyclops
Daph long
Daph midd
Diaptomus
Heterocope
Holopedium
Budy et al in prep.

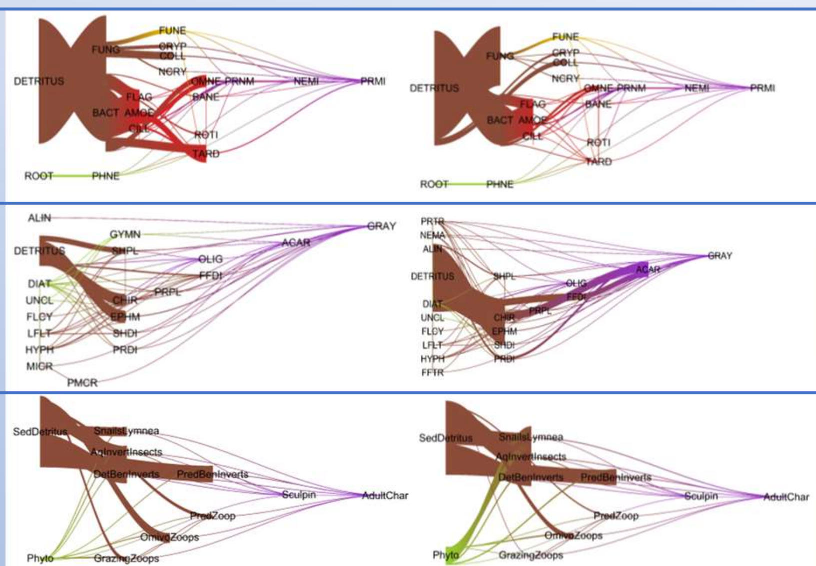
Synthesizing results of nutrient additions across terrestrial, stream, and lake ecosystems



Gough et al. 2016

Food web C & N flux maps

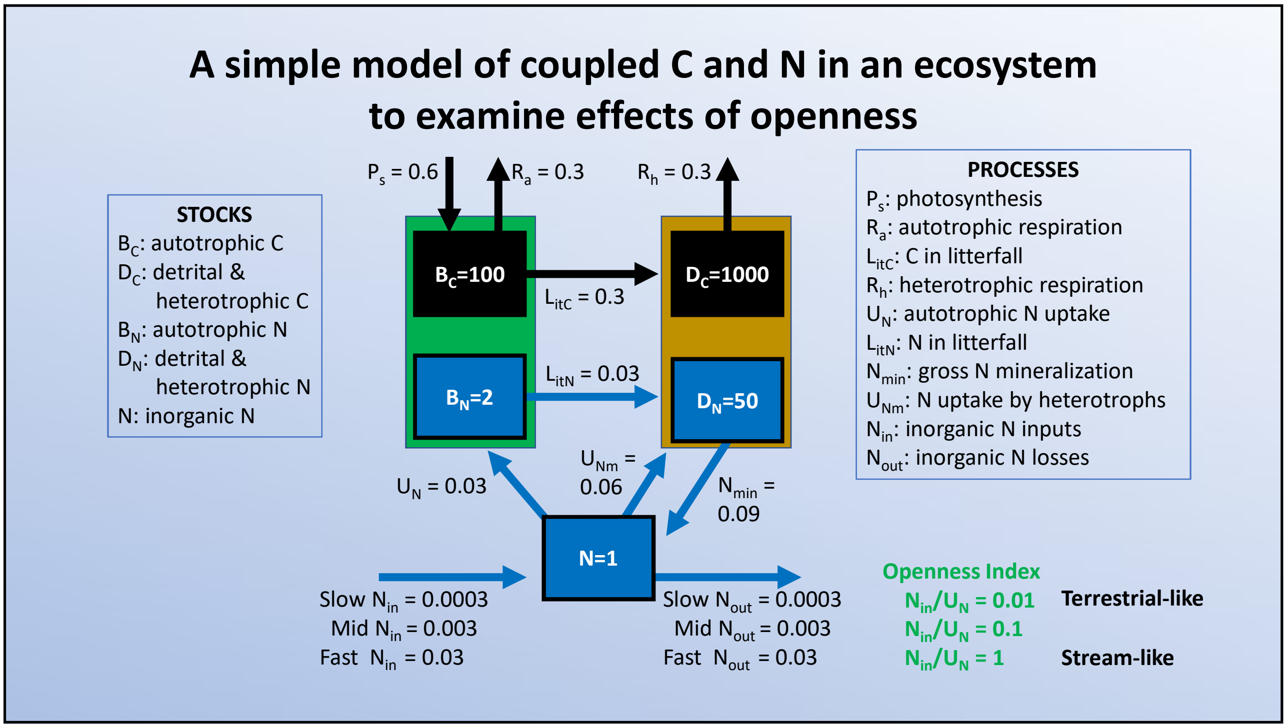
Control **Fertilized**

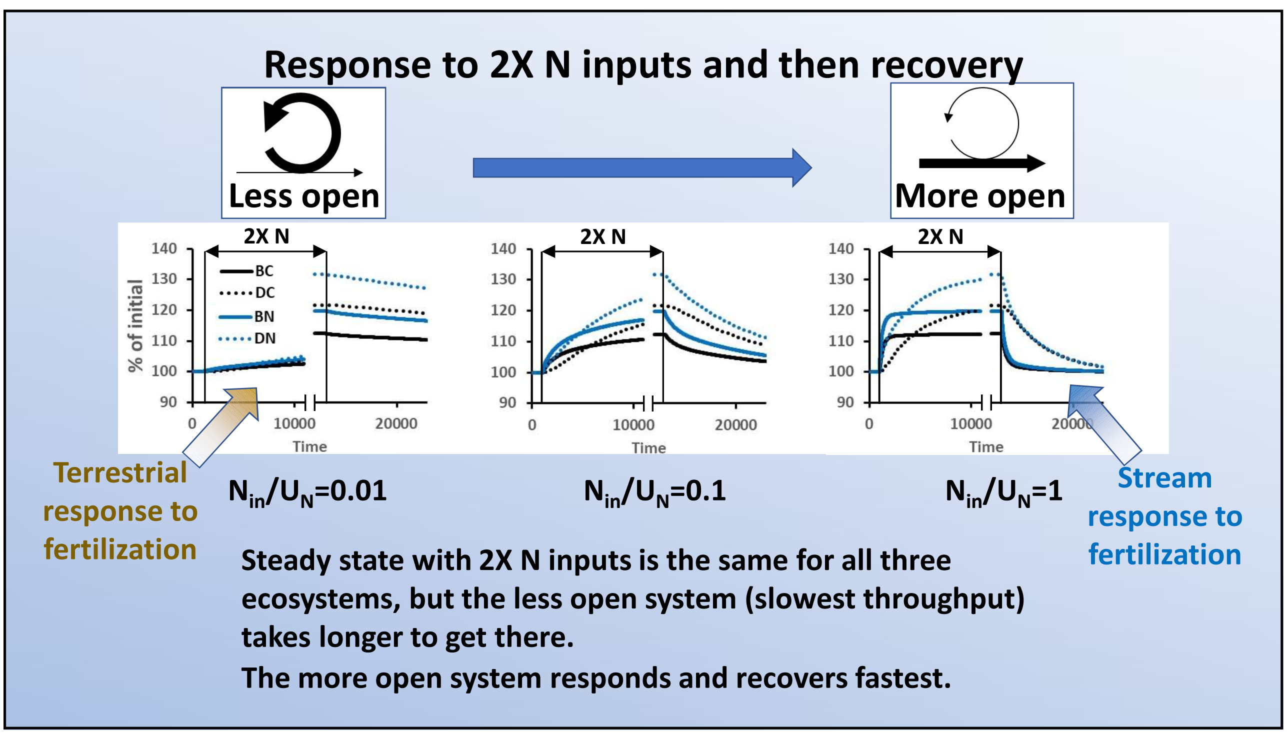


fertilized : Control

	C	CO_2	N_{min}
Dry Heath	0.93	0.70	0.64
Tussock	0.51	0.53	0.52
Shrub	0.49	0.52	0.56
Streams	33.13	34.86	50.67 net N immob.
Lakes	1.73	1.60	1.22 net N immob.

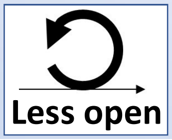
Analysis by John Moore

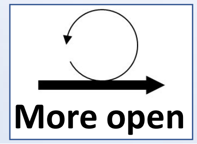

A simple model of coupled C and N in an ecosystem to examine effects of openness
STOCKS
B_C: autotrophic C
D_C: detrital & heterotrophic C
B_N: autotrophic N
D_N: detrital & heterotrophic N
N: inorganic N
P_s = 0.6
R_a = 0.3
R_h = 0.3
B_C=100
D_C=1000
L_{itC} = 0.3
B_N=2
D_N=50
L_{itN} = 0.03
U_N = 0.03
U_{Nm} = 0.06
N_{min} = 0.09
N=1
Slow N_{in} = 0.0003
Mid N_{in} = 0.003
Fast N_{in} = 0.03
Slow N_{out} = 0.0003
Mid N_{out} = 0.003
Fast N_{out} = 0.03
PROCESSES
P_s: photosynthesis
R_a: autotrophic respiration
L_{itC}: C in litterfall
R_h: heterotrophic respiration
U_N: autotrophic N uptake
L_{itN}: N in litterfall
N_{min}: gross N mineralization
U_{Nm}: N uptake by heterotrophs
N_{in}: inorganic N inputs
N_{out}: inorganic N losses
Openness Index
N_{in}/U_N = 0.01 Terrestrial-like
N_{in}/U_N = 0.1
N_{in}/U_N = 1 Stream-like

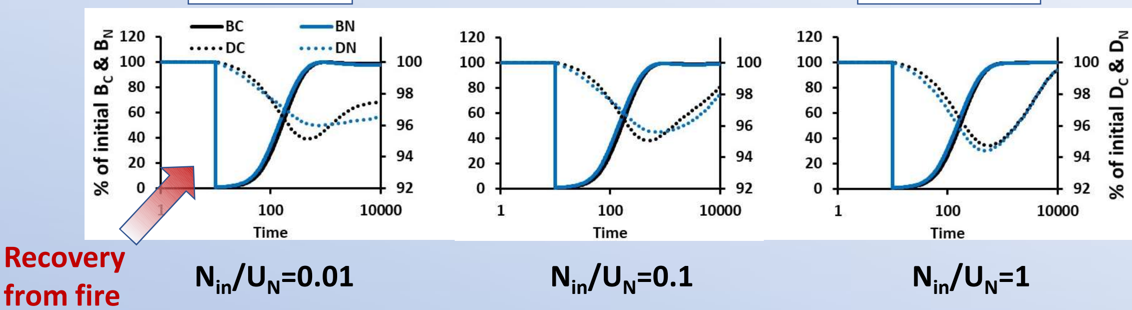

Response to 2X N inputs and then recovery
Less open
More open
2X N
BC
DC
BN
DN
% of initial
Time
Terrestrial response to fertilization
N_{in}/U_N=0.01
N_{in}/U_N=0.1
N_{in}/U_N=1
Stream response to fertilization
Steady state with 2X N inputs is the same for all three ecosystems, but the less open system (slowest throughput) takes longer to get there.
The more open system responds and recovers fastest.

Response to a 99% removal of autotrophic biomass

(~ 3.7% loss of ecosystem N)







N_{in}/U_N=0.01 N_{in}/U_N=0.1 N_{in}/U_N=1

Autotrophic recovery nearly the same in all three ecosystems, fueled predominantly by redistribution of N from detritus to autotrophic biomass.

Heterotroph/detrital recovery strongest in most open ecosystem.

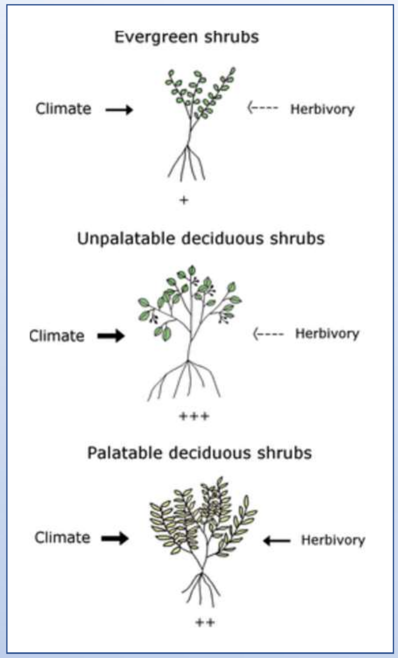
Synthesis: North Slope and Pan-Arctic Analyses

Shrub expansion in the Arctic
Net result of climate warming and herbivory

Small expansion of evergreen shrubs: moderate positive climate effect and weak negative herbivory effect

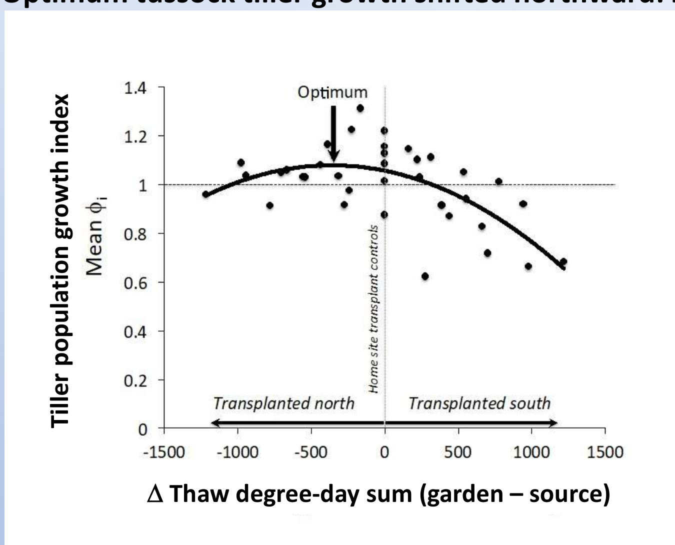
Strong expansion of unpalatable deciduous shrubs: strong positive climate effect and weak negative herbivory effect

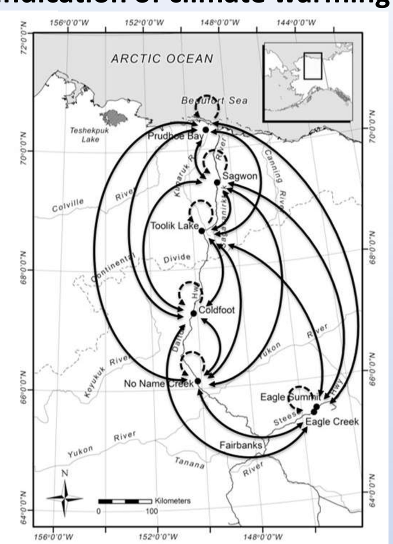
Moderate expansion of palatable deciduous shrubs: strong positive climate effect and strong negative herbivory effect



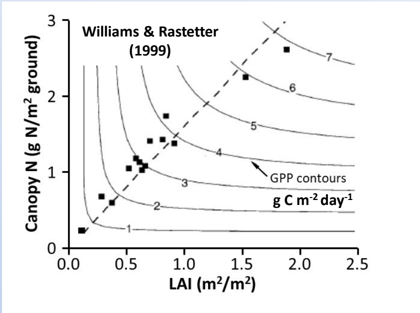
Christie et al. 2015

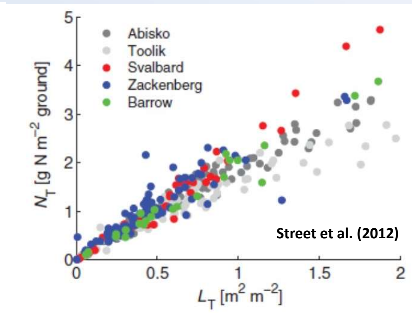
Optimum tussock tiller growth shifted northward: Indication of climate warming?



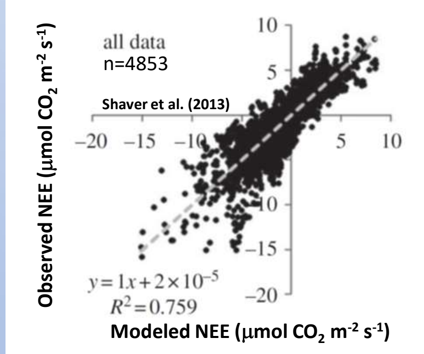


McGraw et al. 2015





There is a remarkable convergence of structure and function among diverse vegetation canopies around the Arctic. NEE predictable from just three variables.



$$N_{EE} = R_x + \left(R_0 L_T e^{\beta T}\right) - \frac{P_{max}}{k} \ln\left(\frac{P_{max} + E_0 I}{P_{max} + E_0 I e^{-kL_T}}\right)$$

N_{EE}: net ecosystem CO_2 exchange(μmol CO_2 $m^{-2}s^{-1}$)

L_T: LAI (m^2m^{-2})

T: air temperature (°C)

I: irradiance (μmol $m^{-2}s^{-1}$)

$R_x = 0.729$

$R_0 = 1.233$

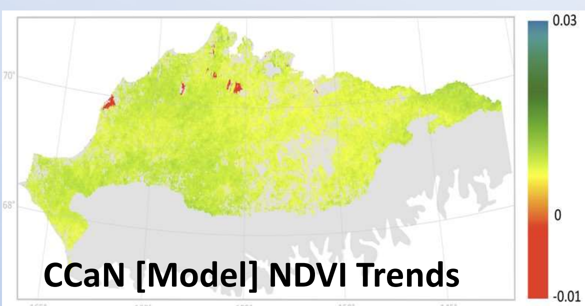
$\beta = 0.046$

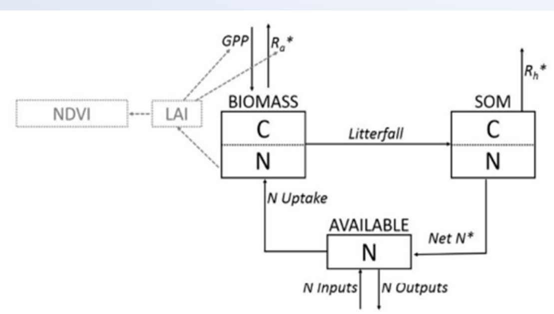
$P_{max} = 15.184$

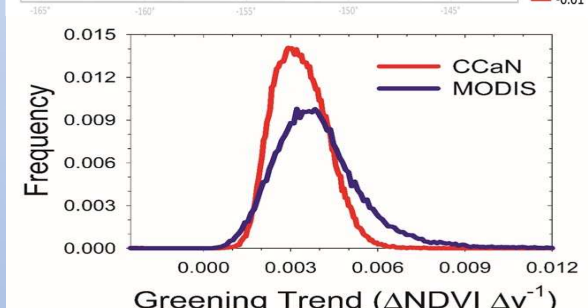
$k = 0.5$

$E_0 = 0.041$

CCaN: Coupled Carbon And Nitrogen model

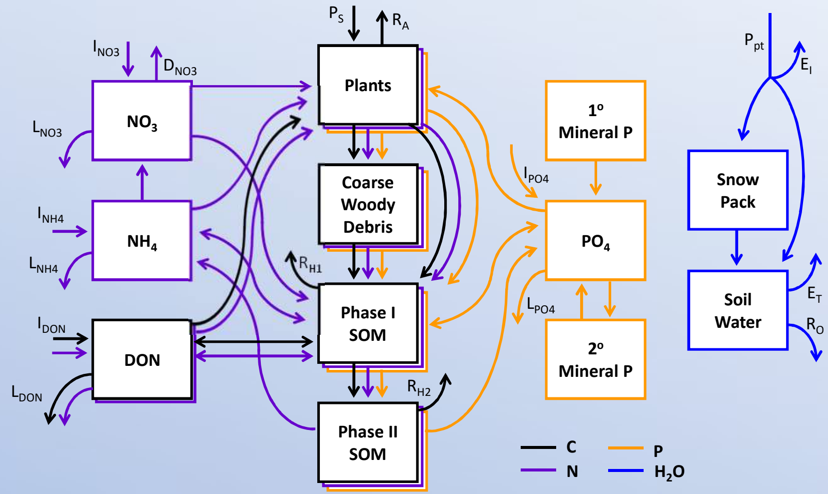




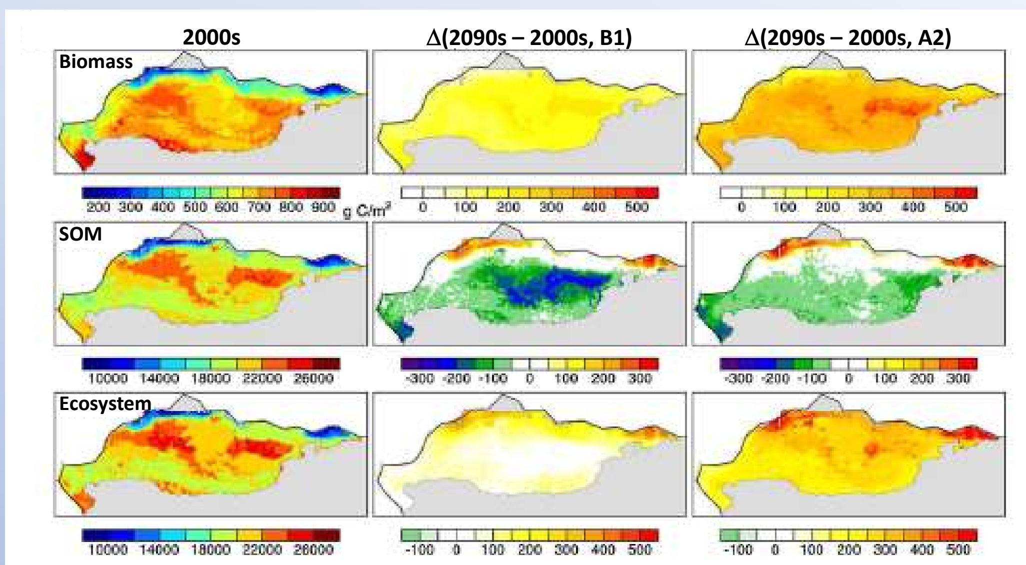


Rocha et al. in prep

The Multiple Element Limitation (MEL) Model

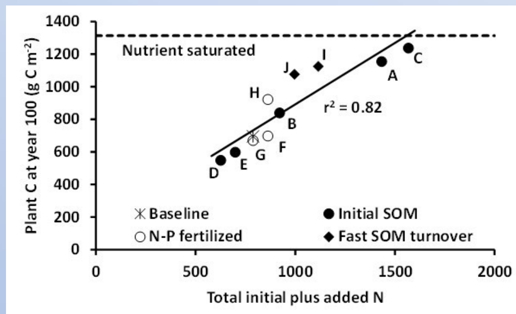


MEL model projections of C in vegetation, soil organic matter, and total ecosystem for IPCC SRES B1 and A2 climate scenarios



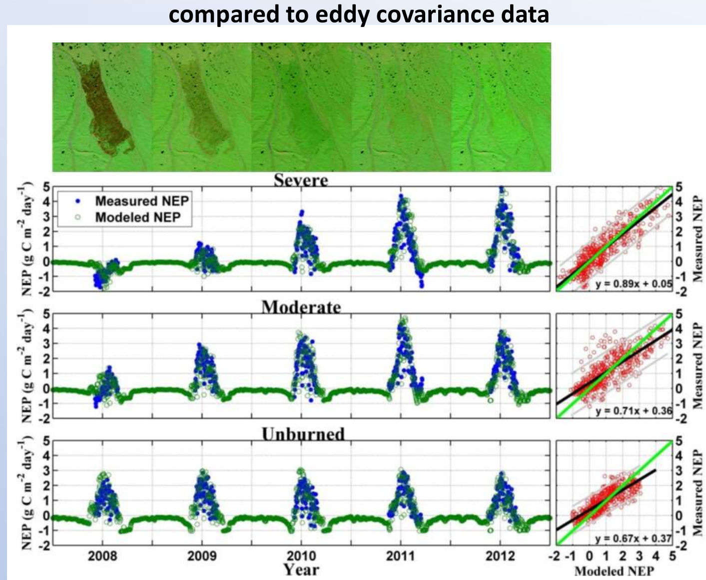
Jiang et al 2016

MEL model analysis of recovery from thermokarst failures



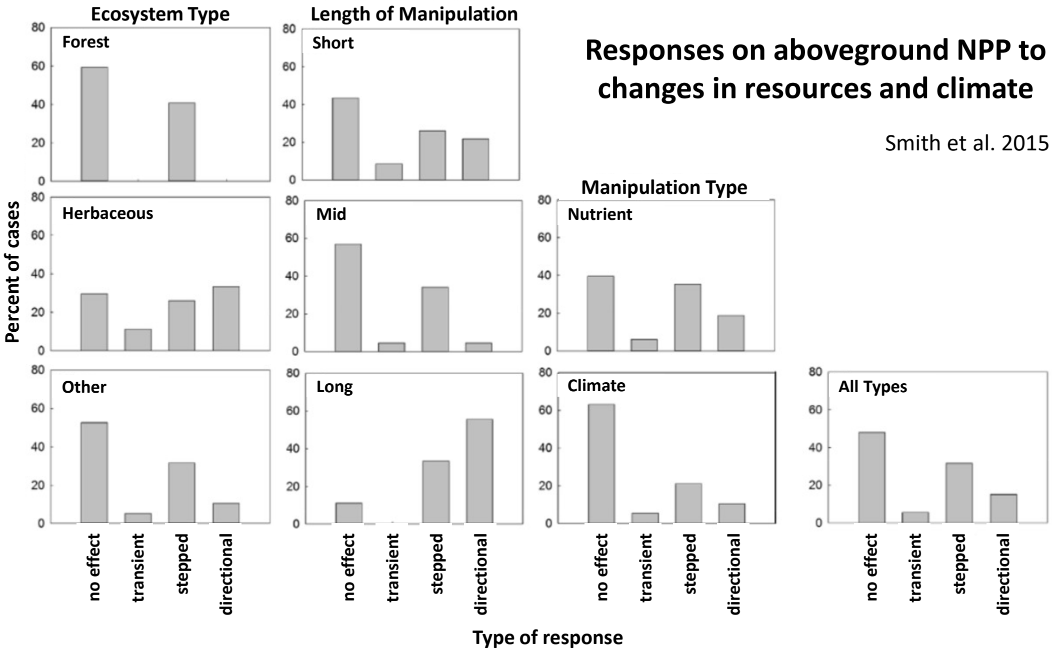
Pearce et al. 2015

MEL model analysis of recovery from wildfire compared to eddy covariance data



Jiang et al. 2015

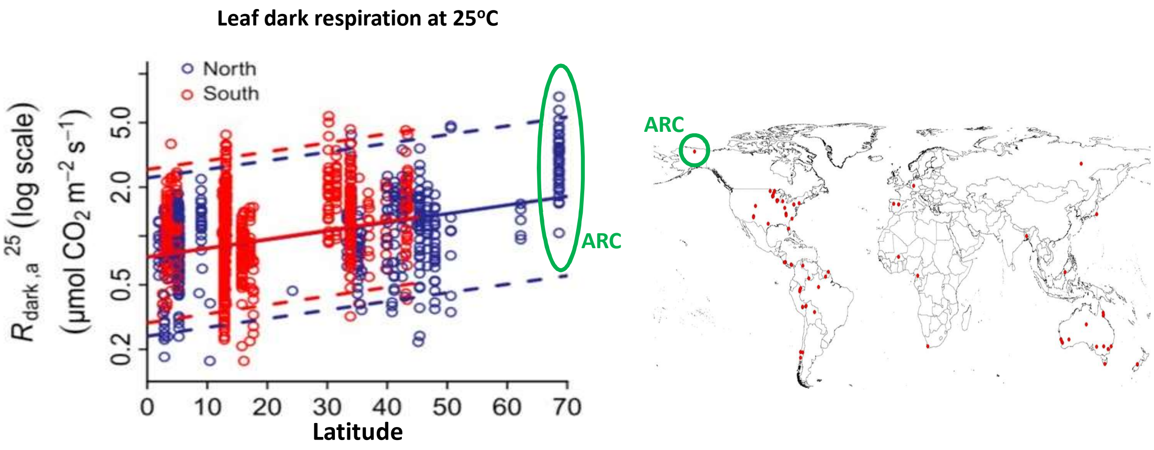
Synthesis: LTER-network analyses



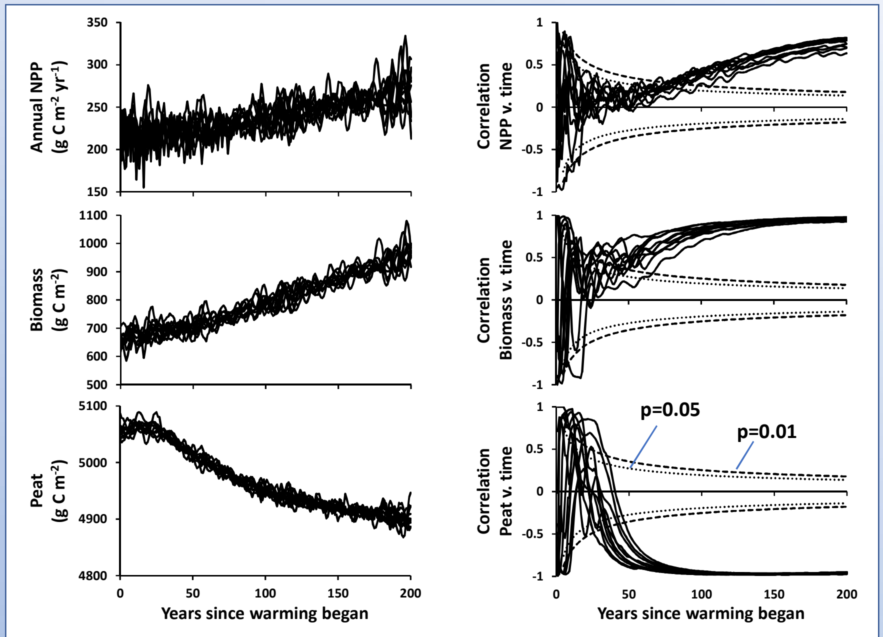
Responses on aboveground NPP to changes in resources and climate

Smith et al. 2015

Plant adaptation to local temperatures evident in longitudinal trend in leaf respiration around the globe



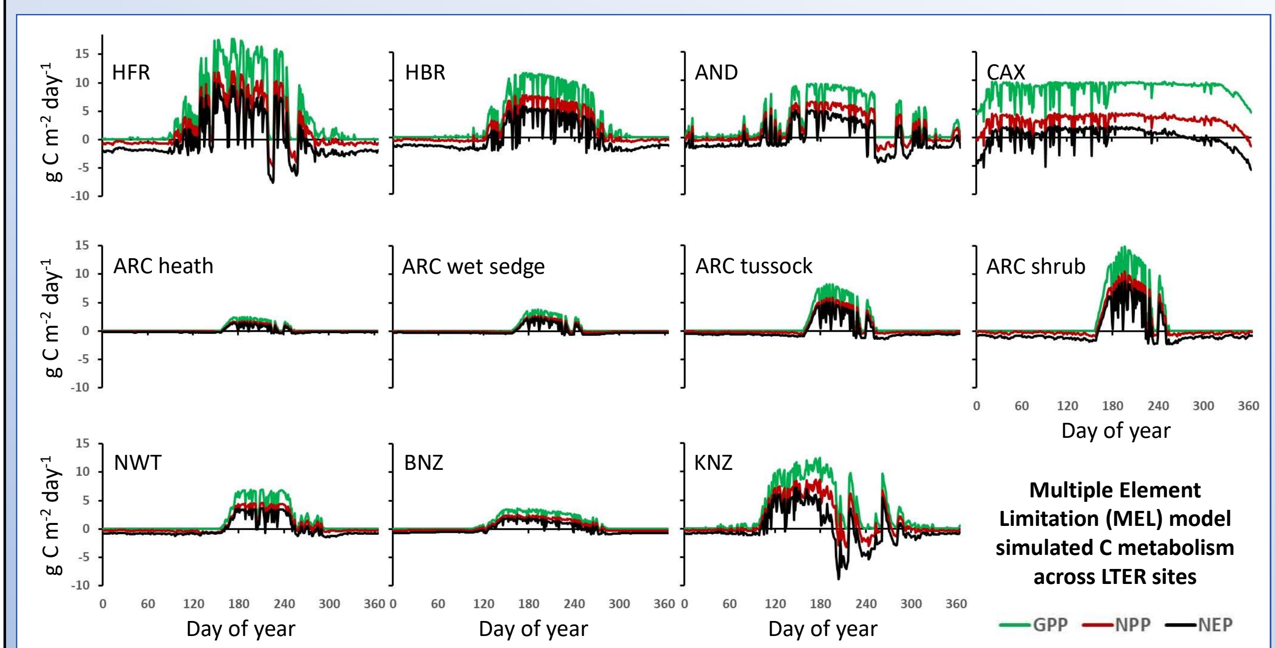
Atkin et al. 2015



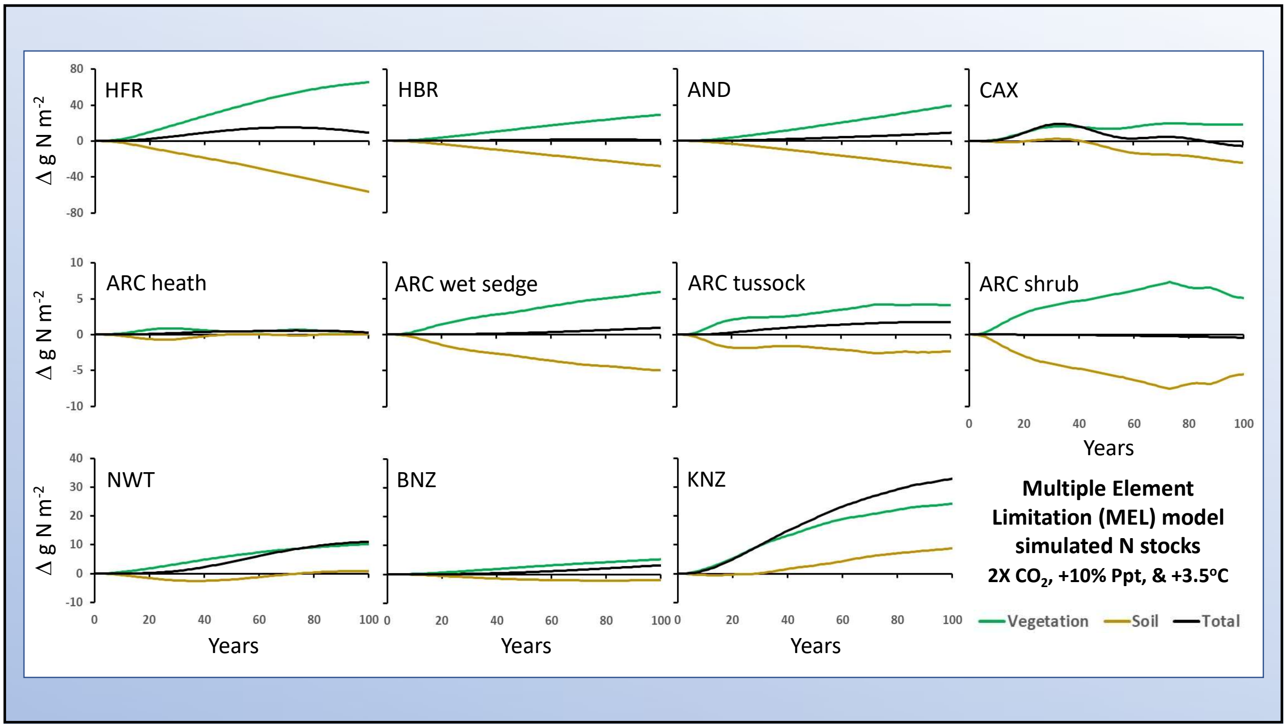
Rastetter et al. (submitted)
Future Trajectories for Ecosystems in the U.S. Long-Term Ecological Research Network: The Importance of Time Lags. Ecosphere.

13 authors from 4 LTER sites (ARC, CCE, CWT, & FCE)

One of five LTER network papers submitted to Ecosphere as a special issue organized by Peter Groffman



Multiple Element Limitation (MEL) model simulated C metabolism across LTER sites


HFR
HBR
AND
CAX
ARC heath
ARC wet sedge
ARC tussock
ARC shrub
NWT
BNZ
KNZ
Δ g N m-2
Years
Multiple Element Limitation (MEL) model simulated N stocks
2X CO2, +10% Ppt, & +3.5ºC
Vegetation
Soil
Total