Permafrost Carbon and Climate Feedbacks in a Warmer World

Dr. Ted Schuur

Bonanza Creek, LTER Annual Symposium

February, 2013

Global Carbon Pools

Global Vegetation C	650 Pg
Global Soil C (1m)	1500 Pg
Atmosphere	841+ Pg

Permafrost Zone Soil C	
Peatlands (several m)	277 Pg
Mineral Soil (3m)	747 Pg
Siberian Deep C (~25m)	407 Pg
Alluvial Deep C (~25m)	241 Pg
	1672 Pg

[Jobaggy et al. 2000, Field et al. 2007, Zimov et al. 2006, Tarnocai 2009, Schuur et al. 2008]

Permafrost Carbon Feedback to Climate

What is the **magnitude**, **timing**, and **form** of the permafrost carbon release to the atmosphere in a warmer world?

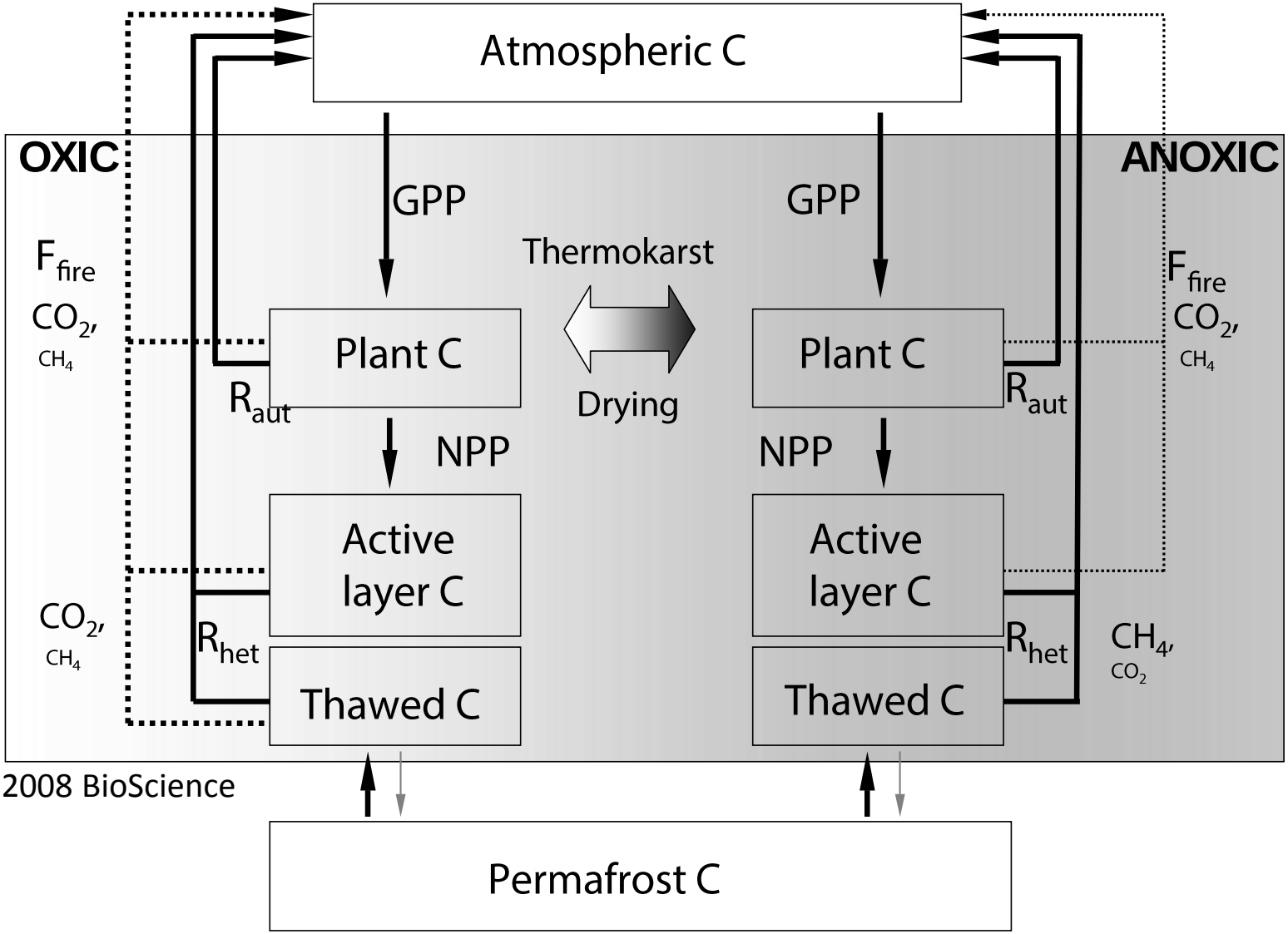
Cumulative C Emissions: 1850-2005 (2012)

Fossil Fuel Emissions	365 Pg
Land Use Change	151 Pg

Permafrost Zone C Emissions: Future?

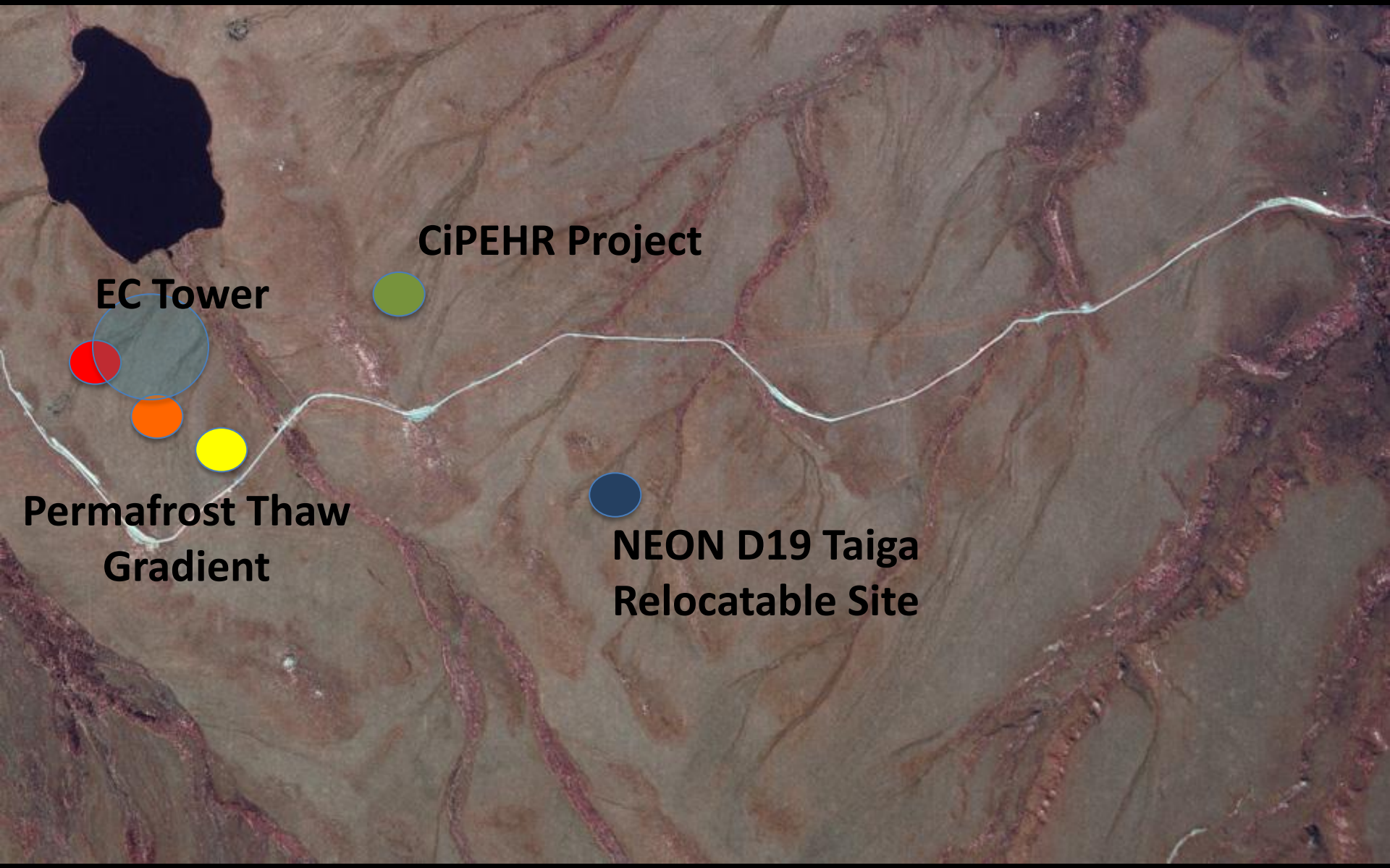
5-30% Loss?	85-501 Pg?

Permafrost Carbon Feedback to Climate

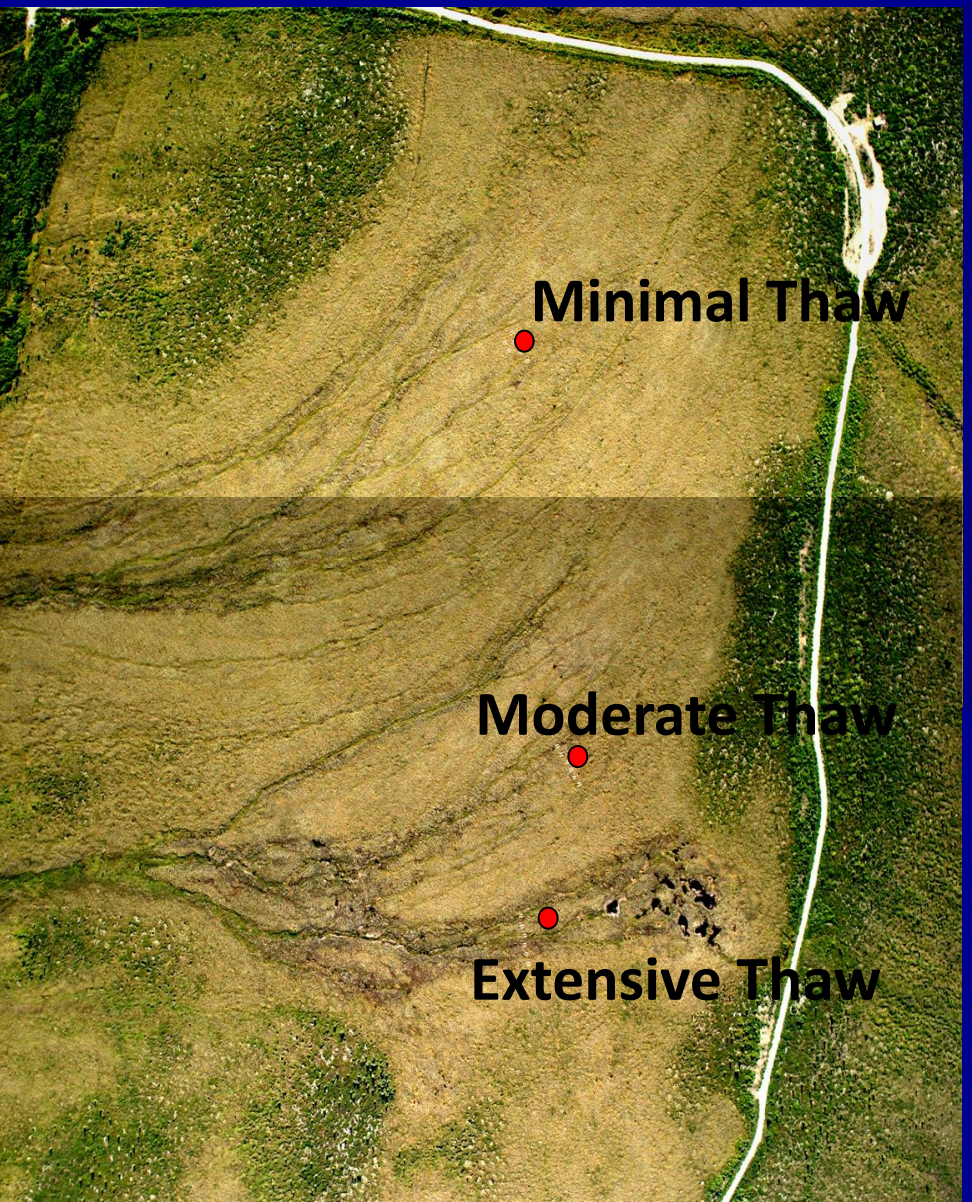


Schuur et al. 2008 BioScience

Eight Mile Lake Study Area

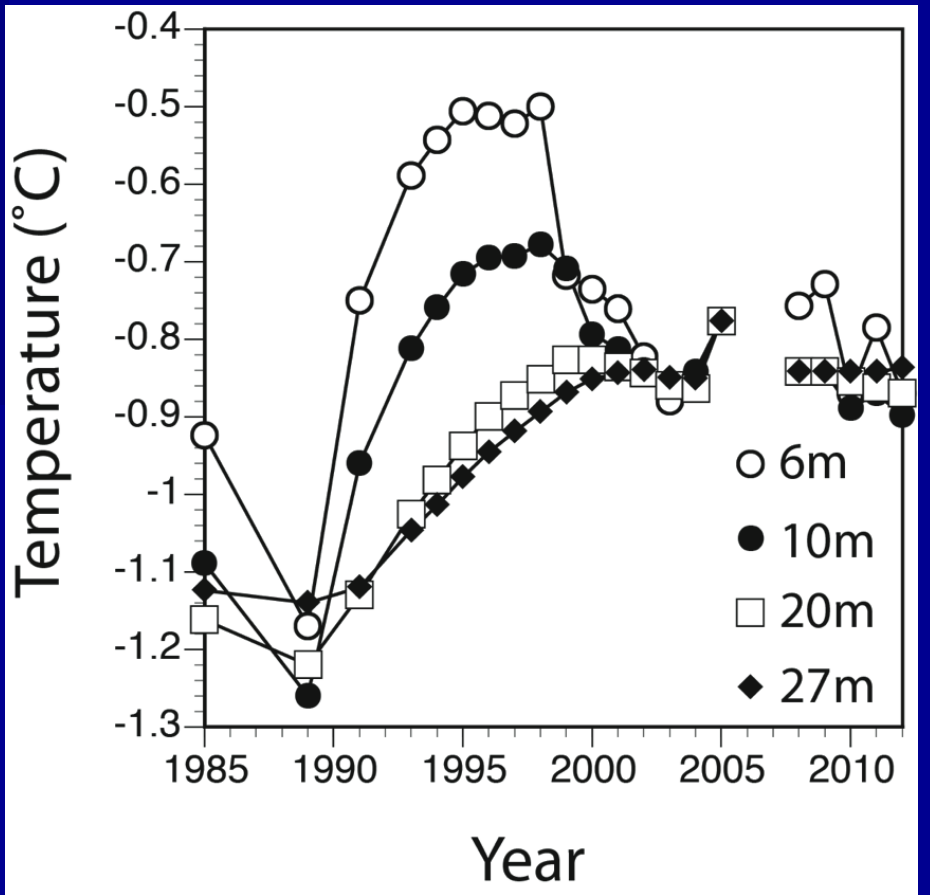


Permafrost Thaw Gradient

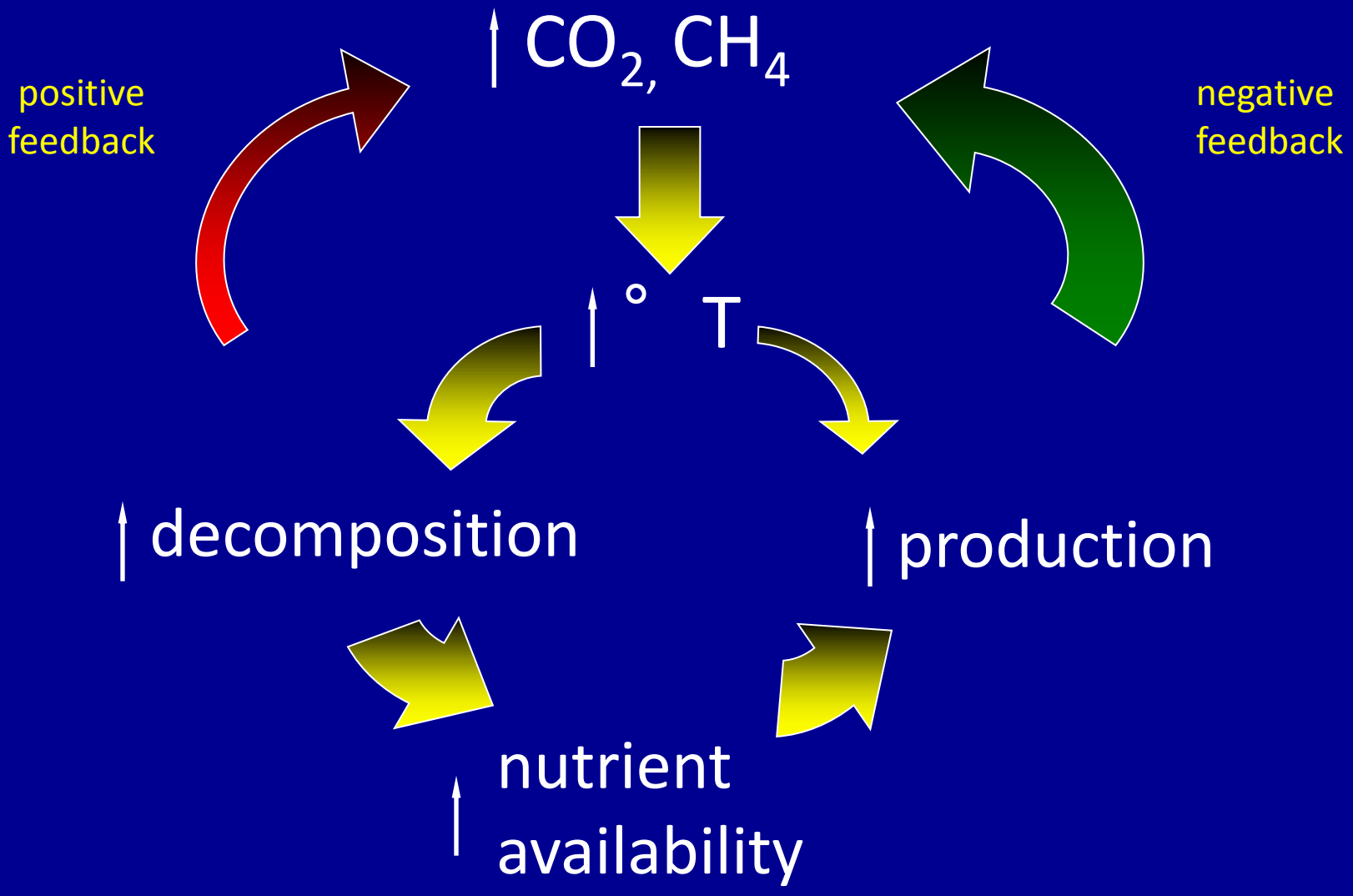


Q1: How does permafrost thaw affect ecosystem carbon balance?

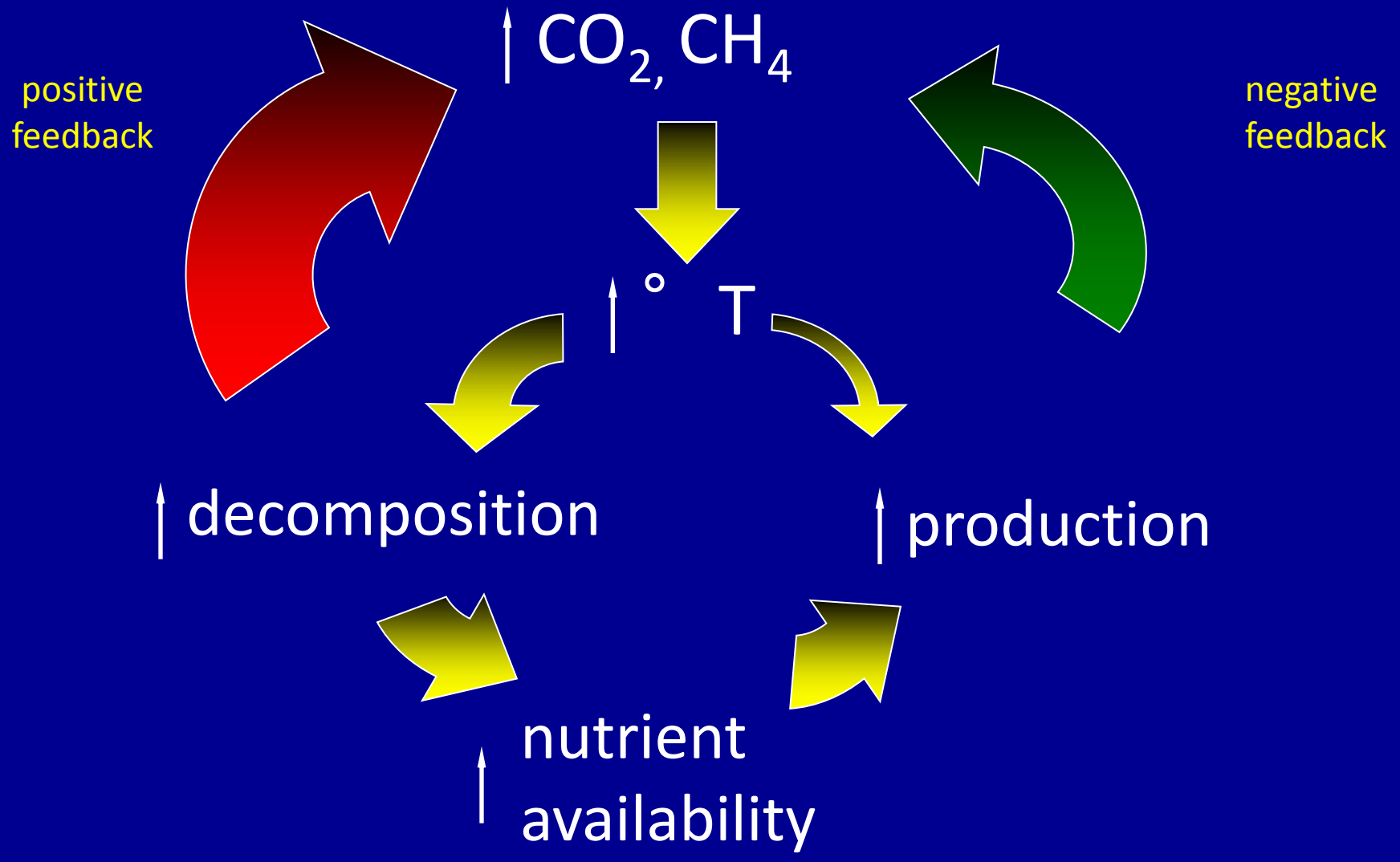
Q2: Does permafrost thaw cause old carbon loss?



Feedbacks to the Carbon Cycle



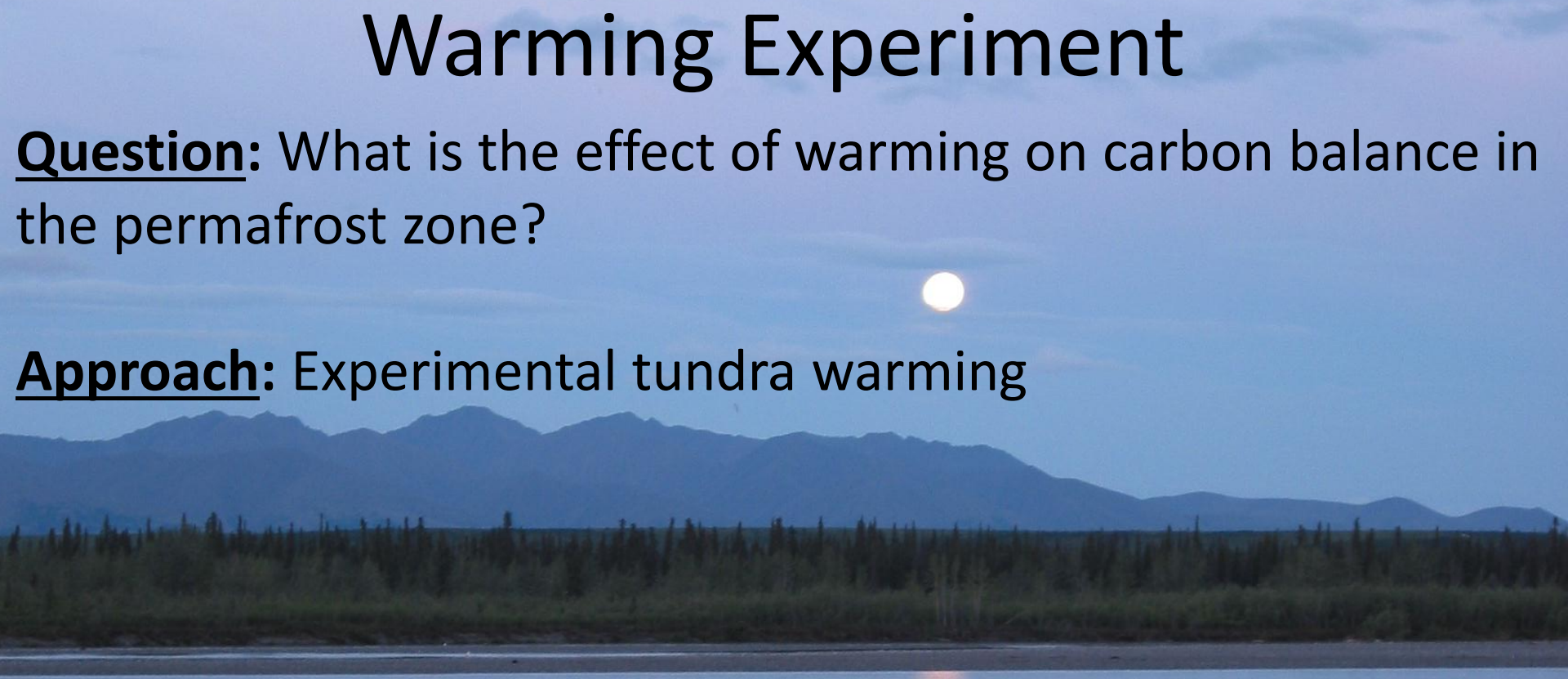
Feedbacks to the Carbon Cycle



Warming Experiment

Question: What is the effect of warming on carbon balance in the permafrost zone?

Approach: Experimental tundra warming



Issues: Previous tundra warming experiments mostly have warmed air or surface soil, but fail to degrade permafrost

Snowfence experiments have warmed deep soil but typically result in extra water inputs or delayed spring

CiPEHR Project

(Carbon in Permafrost, Experimental Heating Research)

Two Treatments, Factorial

Winter Warming (Snow Fence + Snow Removal)

Summer Warming (Open Top Chamber)

Annual Warming (Combination)

Control (Ambient)

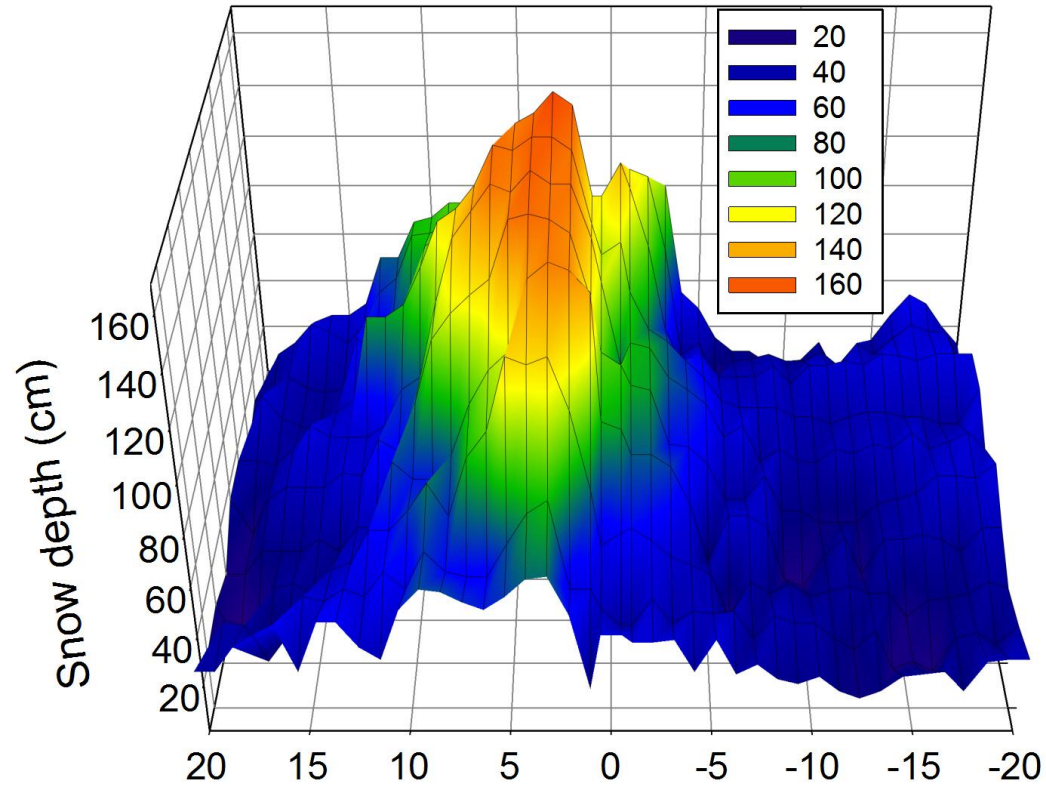
Replicated: 6 times w/ subreplicate plots

Established: Summer 2008

Sue Natali

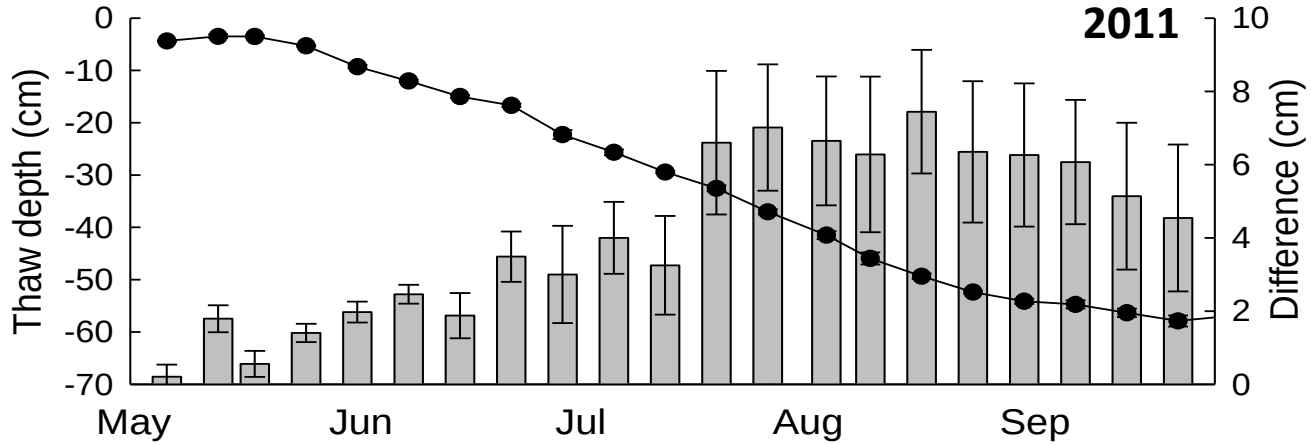

2-3

Winter Warming Causes Surface Permafrost Degradation



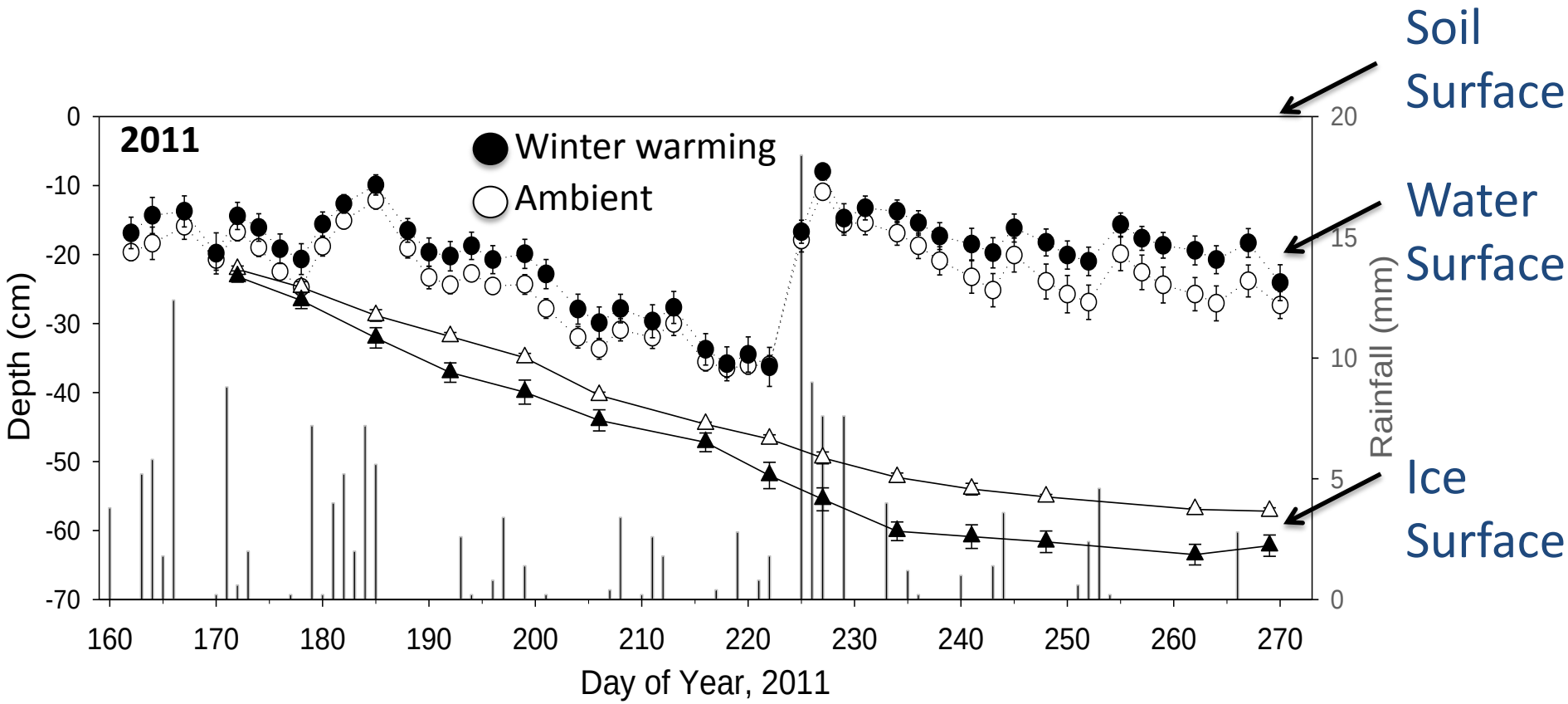
Winter warming plots
Increased T in winter and summer, at depth

Summer warming plots
No soil warming
Midday air temp ~+1°C



Natali et al. 2010,
Global Change Biology

Winter Warming Increases Water Table



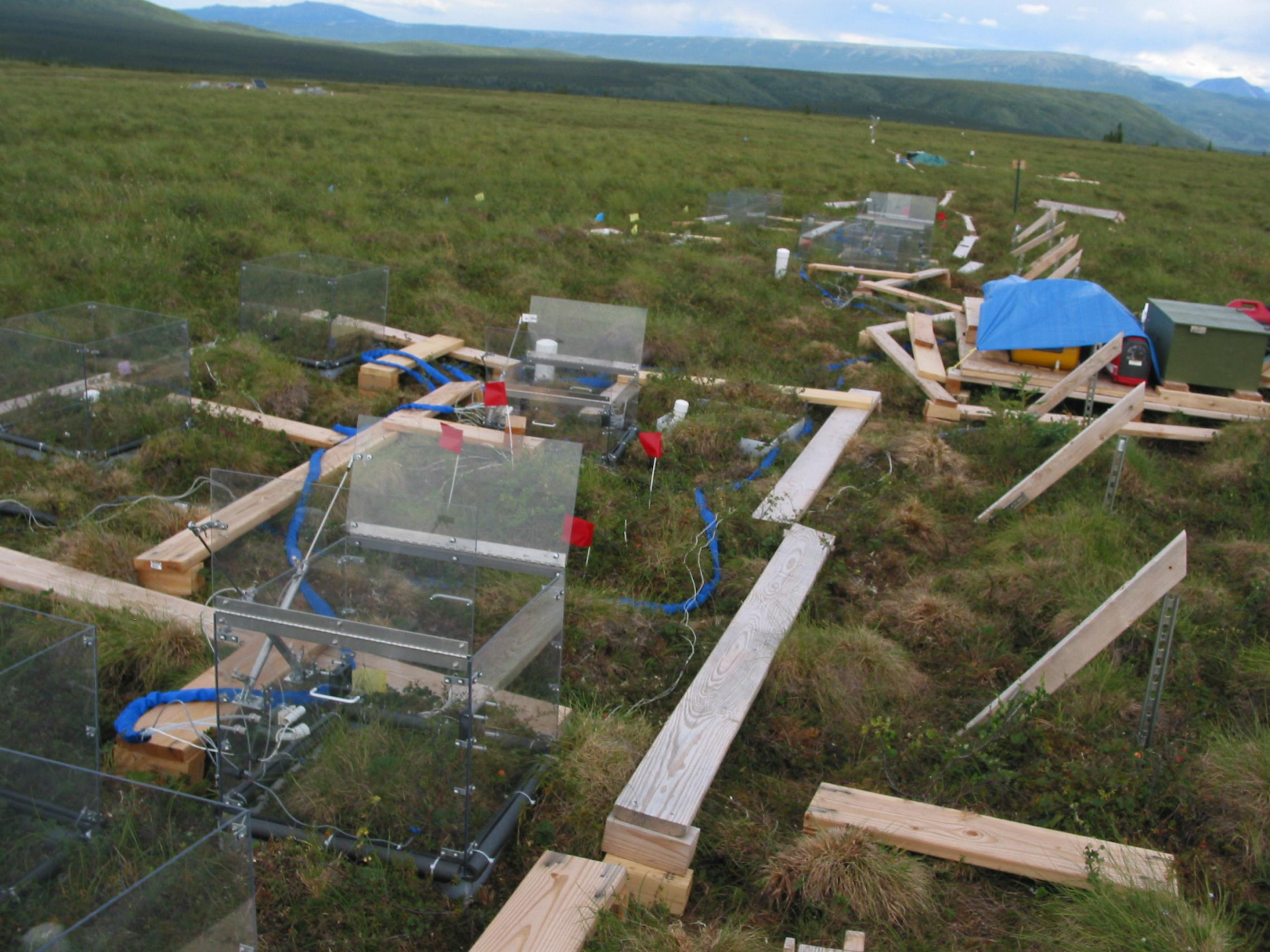
Winter warming

50% increase in total height of water table

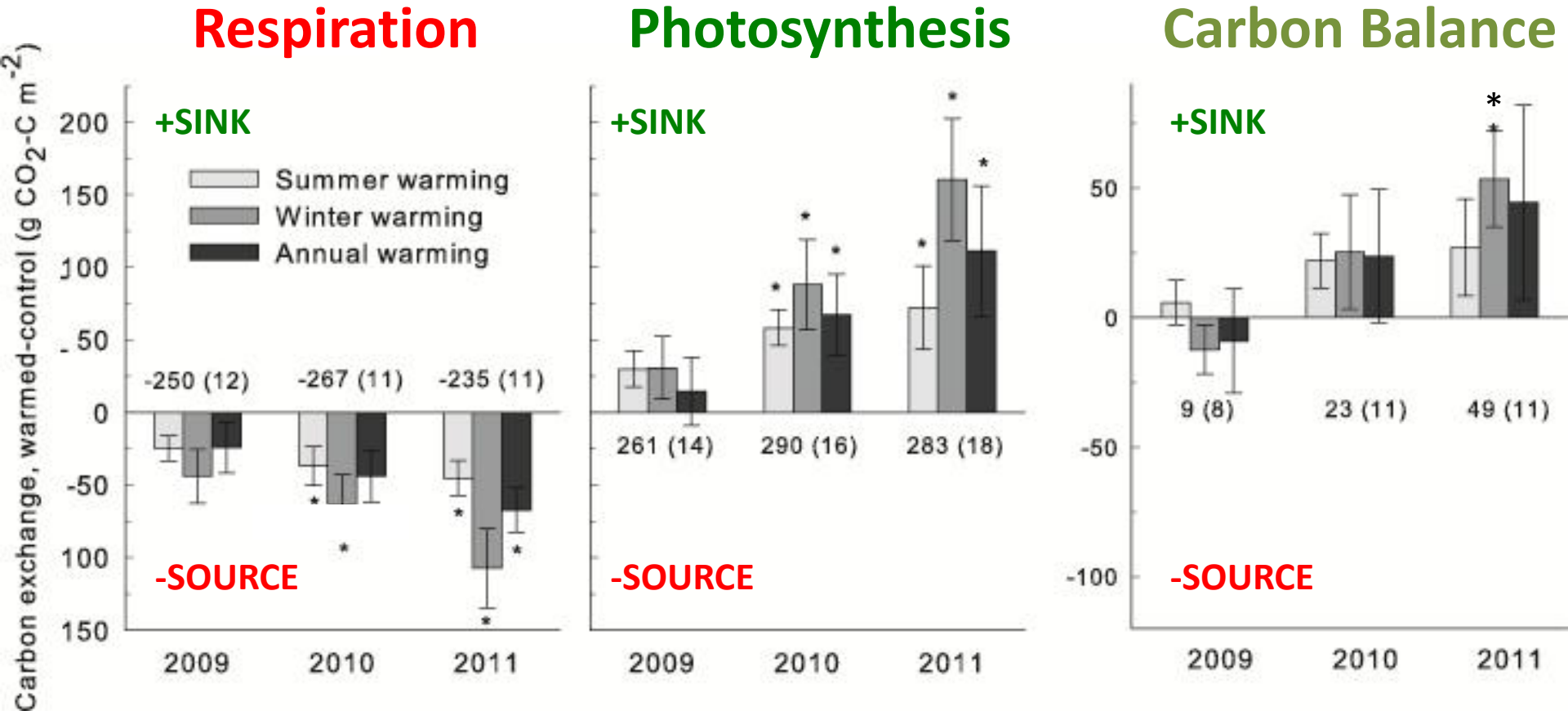
Increased surface soil moisture

Dryper: Water Table Manipulation in 2011

(NSF Fellowship + NSF Grant to S. Natali)



Growing Season Carbon Fluxes



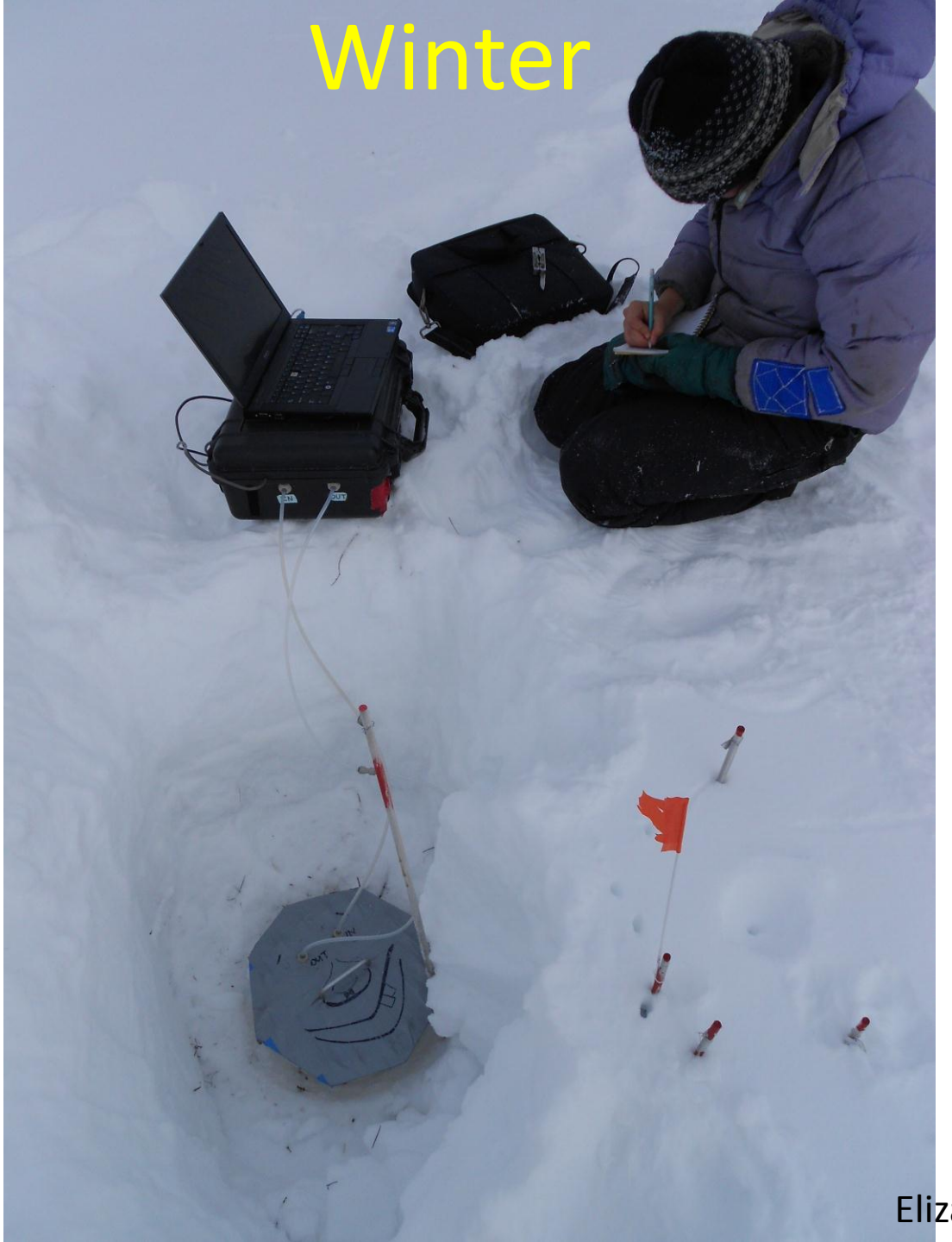
Summer warming: NEE no difference from control (but **C sink**)

Winter warming: +NEE (**C sink**)

Annual warming: NEE no difference (but **C sink**)

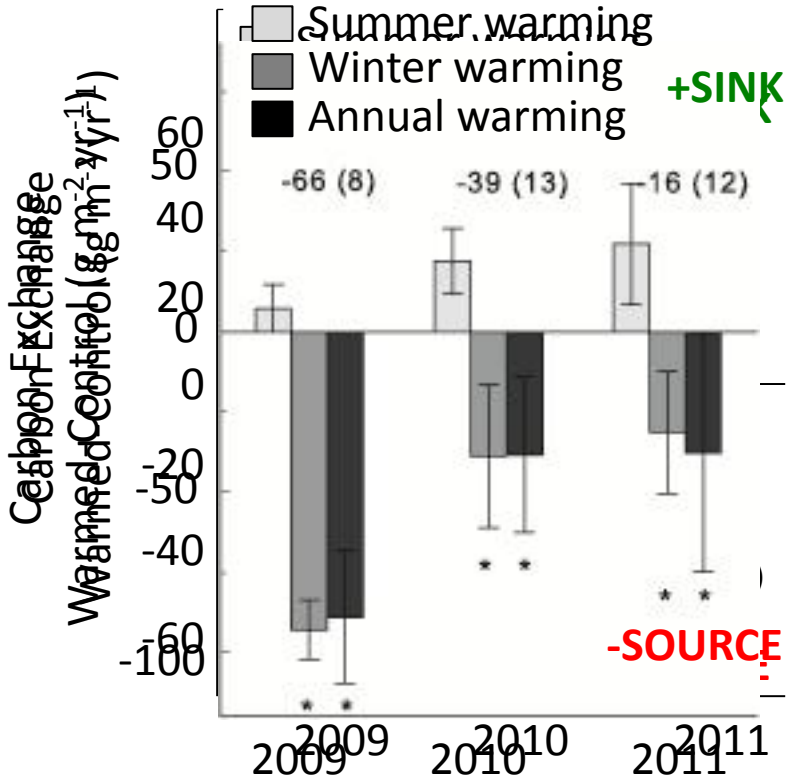
Natali et al. 2010
Natali et al. in prep
Verity Salmon PhD

Winter



Elizabeth Webb – MS

Annual Carbon Balance

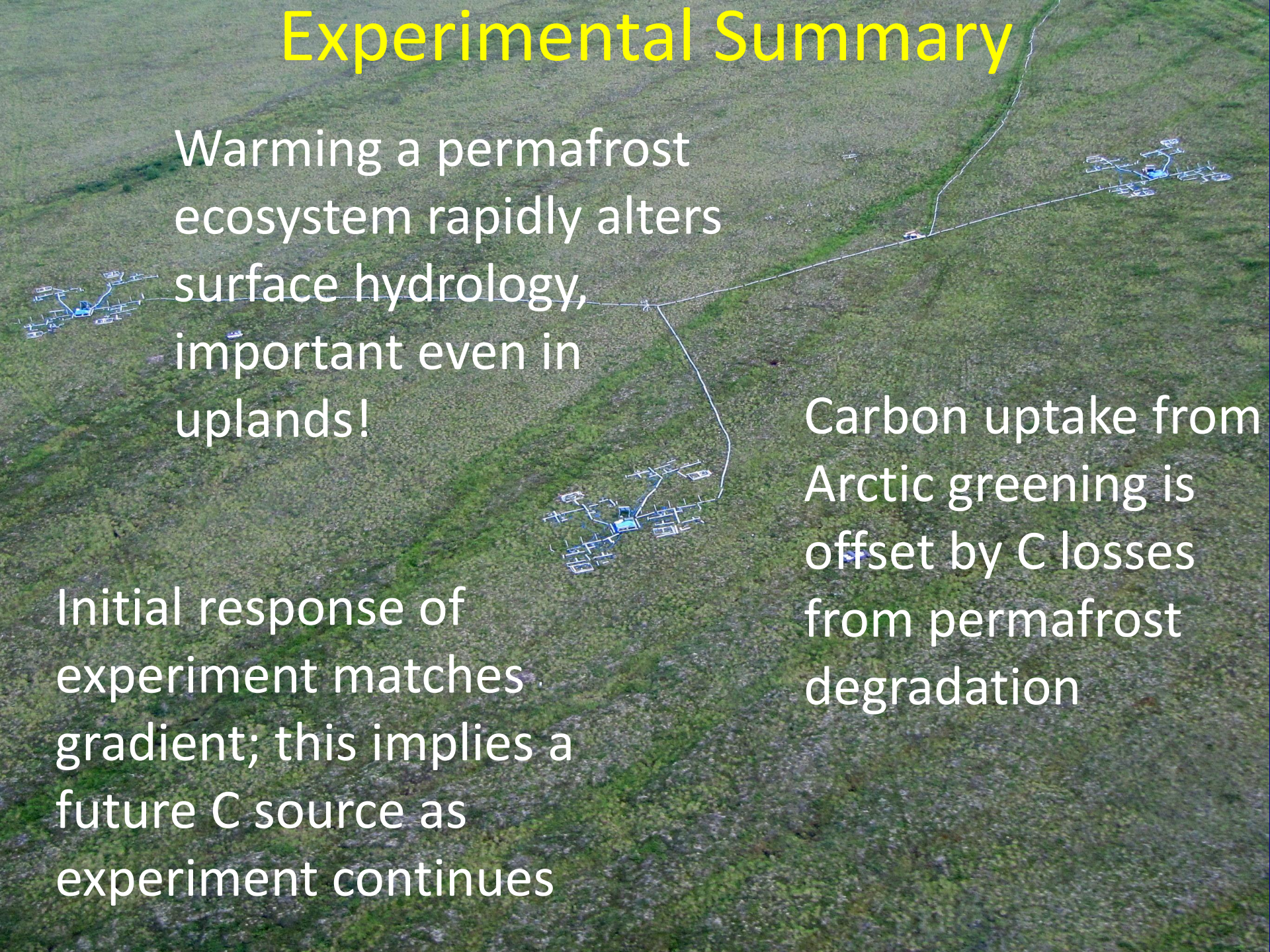


Summer warming: +NEE no difference from control, but (**C neutral 2 of 3 yrs**)

Winter warming: Initial source, then (**C neutral 2 of 3 yrs**)

Annual warming: Same as WW (**C neutral 2 of 3 yrs**)

Experimental Summary



Warming a permafrost ecosystem rapidly alters surface hydrology, important even in uplands!

Carbon uptake from Arctic greening is offset by C losses from permafrost degradation

Initial response of experiment matches gradient; this implies a future C source as experiment continues

Permafrost Carbon Emissions

Permafrost Zone Soil C

Gelisol Soil Order (3m)*

818 Pg

x 9-13%

77-106 Pg**

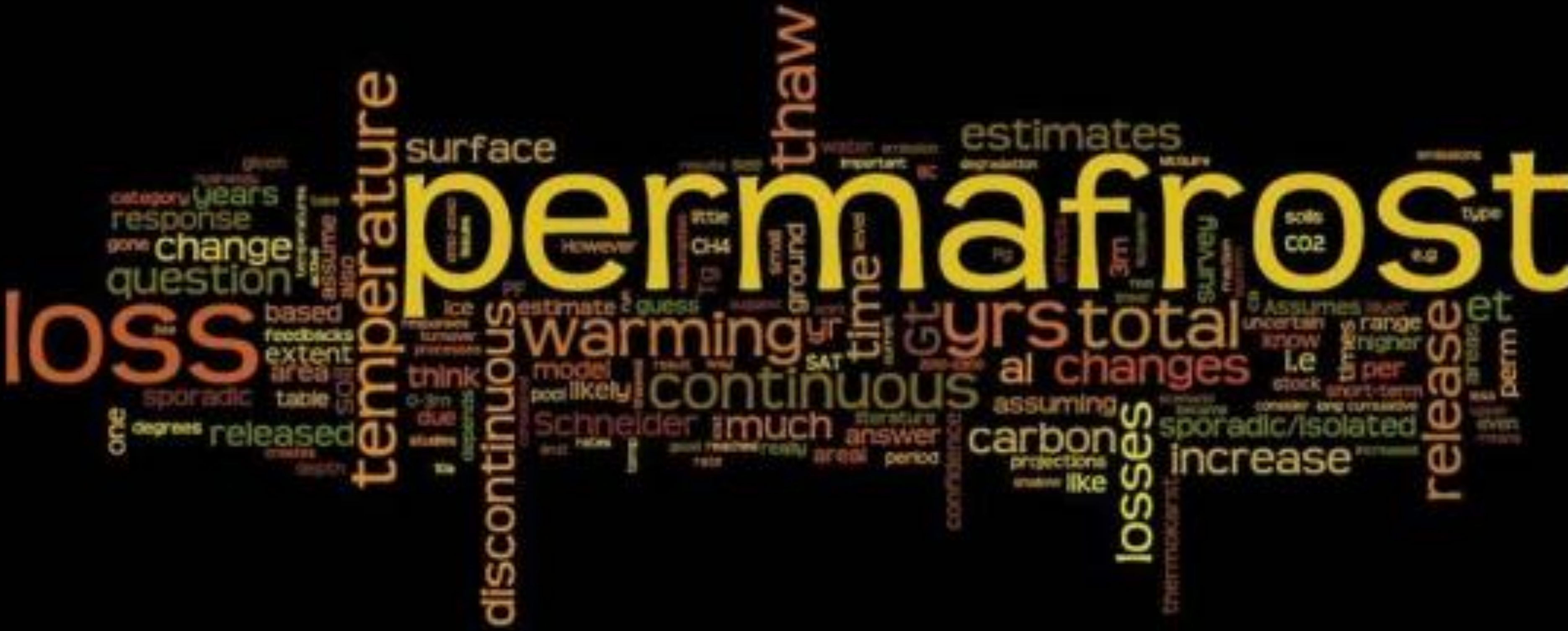
Permafrost C Loss

0.8-1.1 Pg/yr

Land Use Change***

0.9±0.7 Pg/yr

*Tarnocai et al. 2009, **Schuur et al. 2009, ***van der Werf et al. 2009


permafrost
loss
temperature
thaw
discontinuous
continuous
warming
yrs
total
estimates
surface
losses
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carbon
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CO2
CH4
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SAT
like
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confidence
depth
due
ice
However

Vulnerability of Permafrost Carbon

Research Coordination Network (RCN)

http://www.biology.ufl.edu/permafrostcarbon/

PIs: Ted Schuur, A. David McGuire

Steering Committee: Josep G. Canadell, Jennifer W. Harden, Peter Kuhry, Vladimir E. Romanovsky, Merritt R. Turetsky

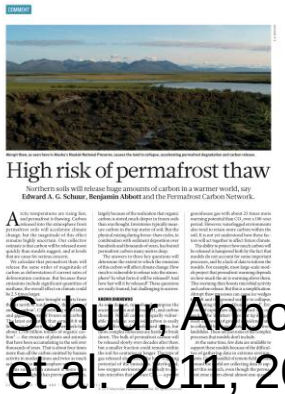
Postdoctoral Researcher: Christina Schädel

Core funding: NSF

Additional Workshop funding: WCRP·SCAR CliC, IASC, USGS science for a changing world, Department of Energy, United States of America

Workshop: May 2013; Annual Meeting @ AGU

Permafrost Carbon Feedback: Expert Assessment



High risk of permafrost thaw

Northern soils will release huge amounts of carbon in a warmer world, say Edward A. G. Schuur, Benjamin Abbott and the Permafrost Carbon Network.

High Warming Scenario (2100): **162-288 Pg C** (in CO_2 equivalents)

Low Warming Scenario (2100): **54-90 Pg C** (in CO_2 equivalents)

2.3% CH_4 = half of emissions in CO_2 equivalents

Schuur, Abbott et al. 2011, 2013

Special Issue: Environmental Research Letters; March 31, 2013

Conclusions

Permafrost C pools are large and sensitive to climate change on decadal to century time scale (4-13%)

Experimental permafrost degradation was consistent with C emissions observed from natural thaw

Future permafrost C emissions will not overshadow fossil fuel, but will serve to accelerate pace of climate change (weakening biospheric sink)

Permafrost C emissions should be accounted for when planning mitigation strategies for avoiding dangerous climate change

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