Carbon cycling in thawing permafrost peatlands: BNZ LTER

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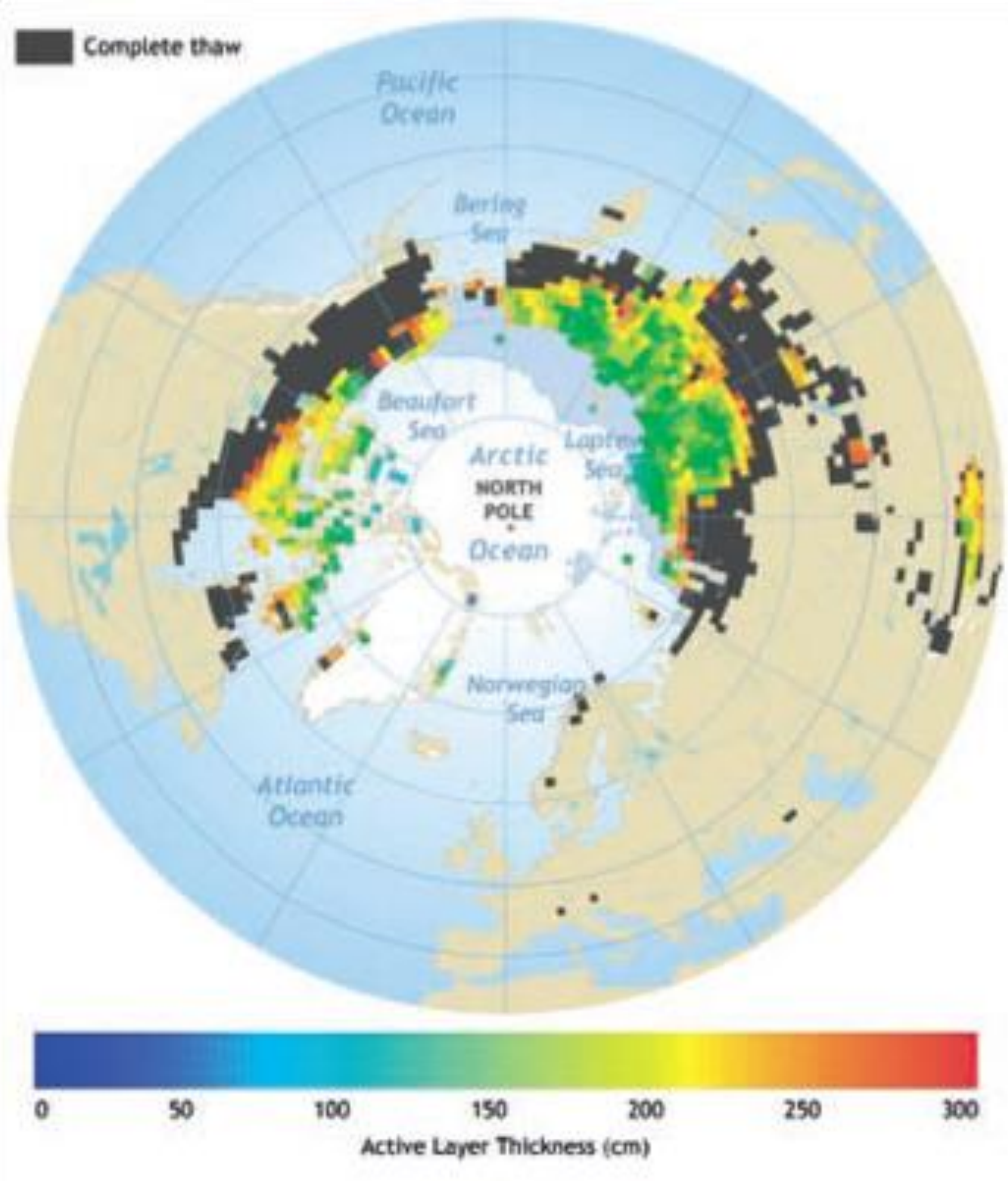
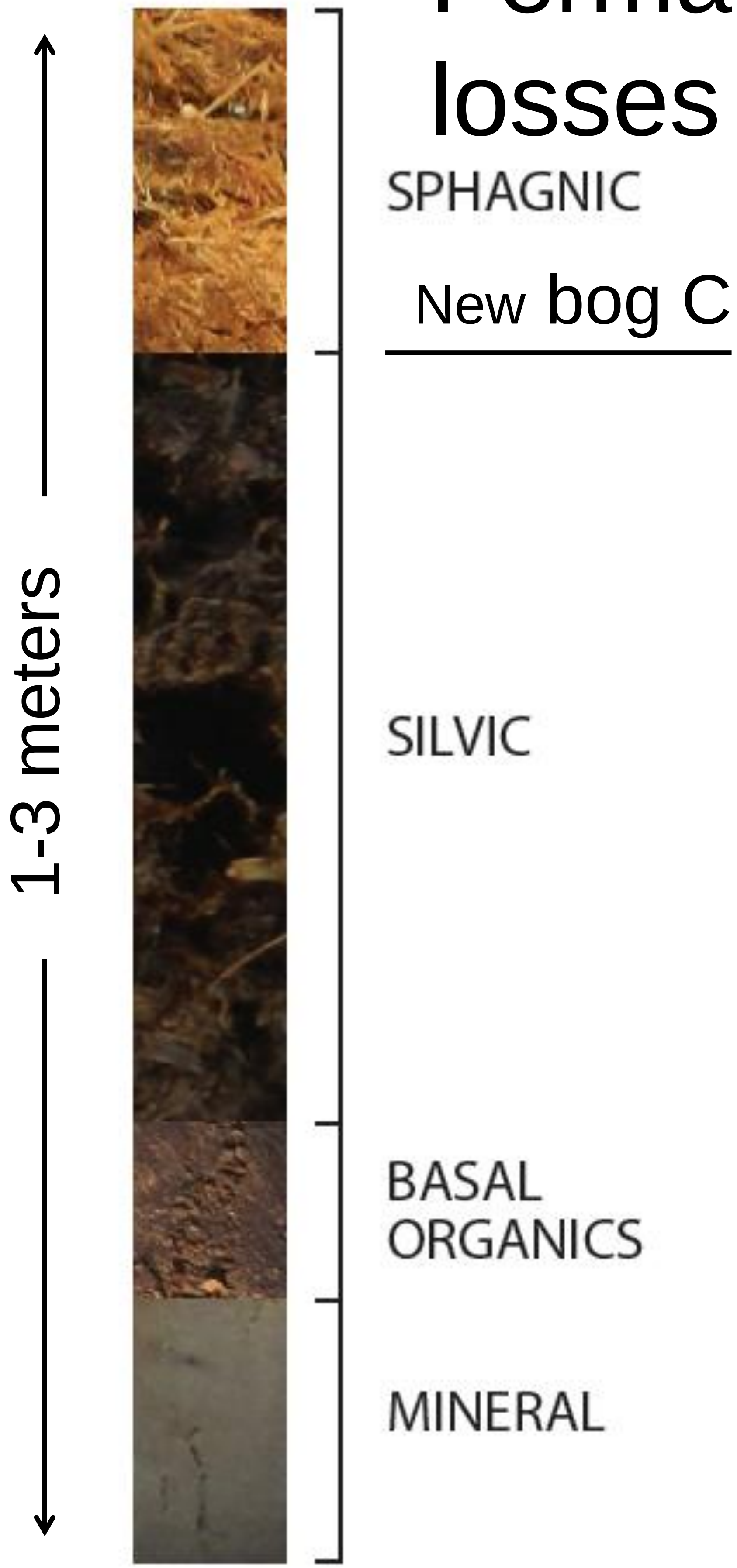
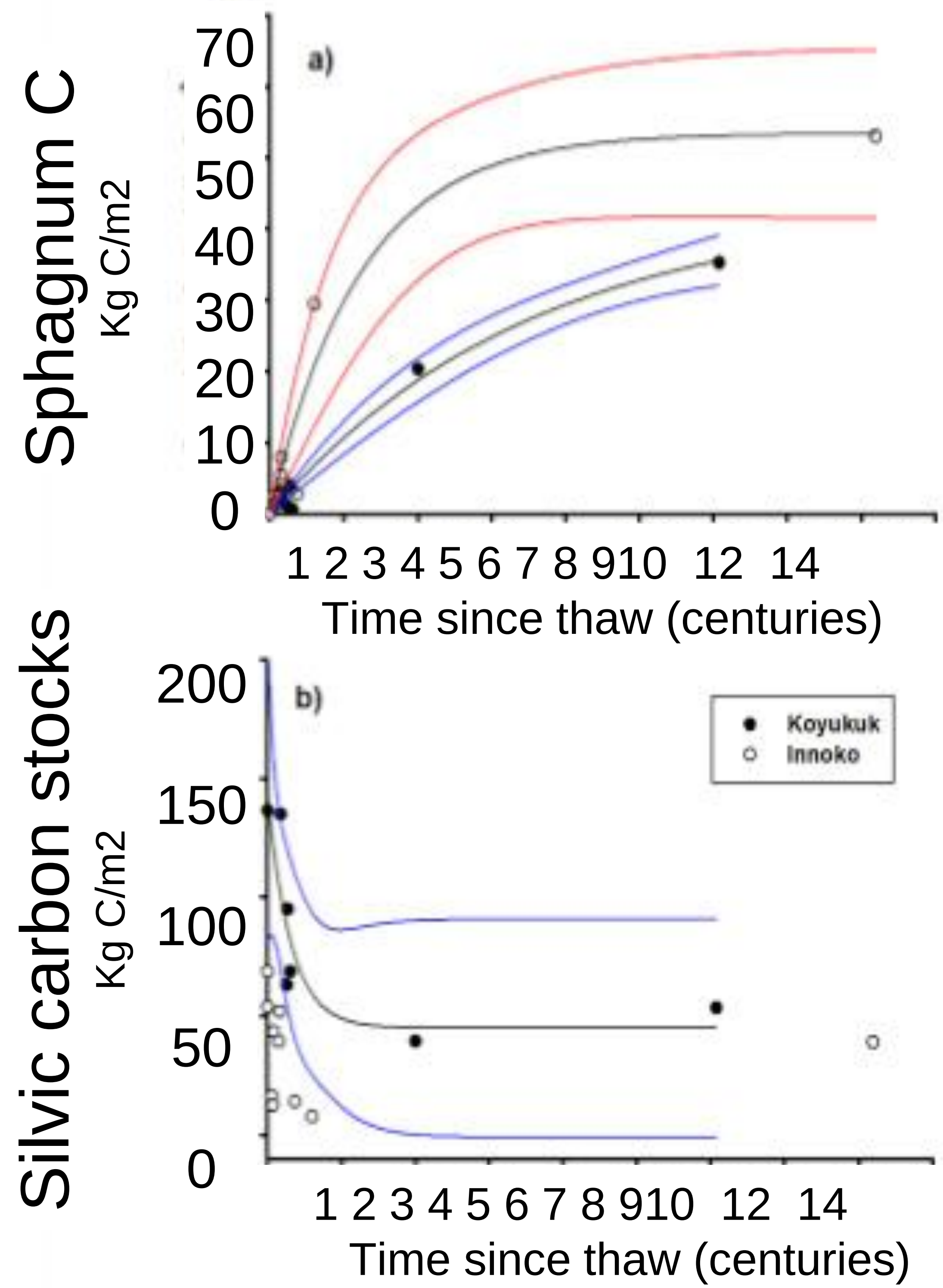
Model projections indicate widespread loss of near surface permafrost by 2100



Schaefer et al., 2011

Permafrost thaw results in large carbon losses from lowland boreal ecosystems



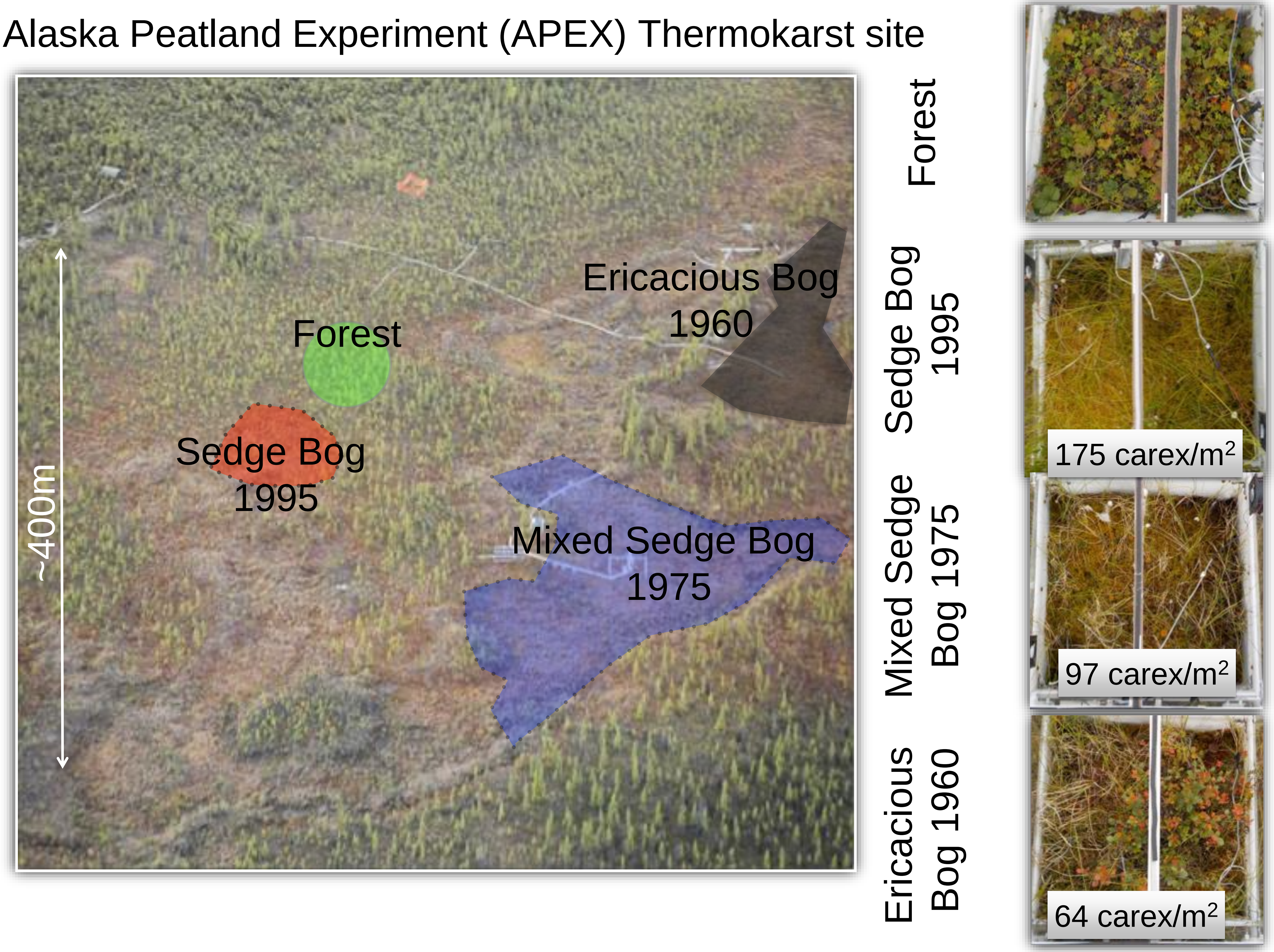


Data from J. O'Donnell (2012) and M. Jones (2016)

Questions

- Do we observe large (>>kg C/m2) losses of C from the transformation of the permafrost plateau into bogs at APEX.
- Do we observe highest rates of microbial activities in bogs undergoing the most rapid transformation (youngest bogs)? And why?
- How do physical/mechanical changes in permafrost influence microbial activities in permafrost pre-thaw?

Alaska Peatland Experiment (APEX) Thermokarst site



Date of thaw

Soil coring
Carbon
Macrofossils
^{14}C
FTIR

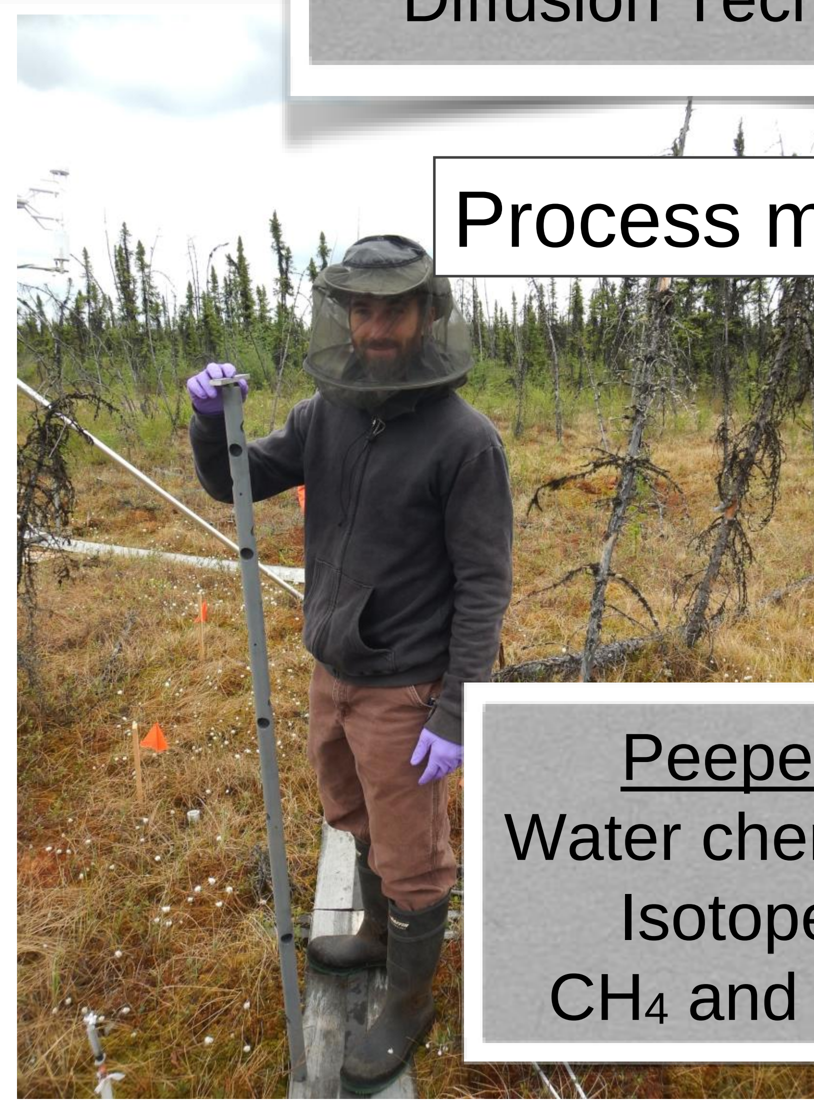
Carbon balance

Fluxes
Net Ecosystem Exchange
CH_4 flux
Autochambers and
Diffusion Technique

Microbial potentials

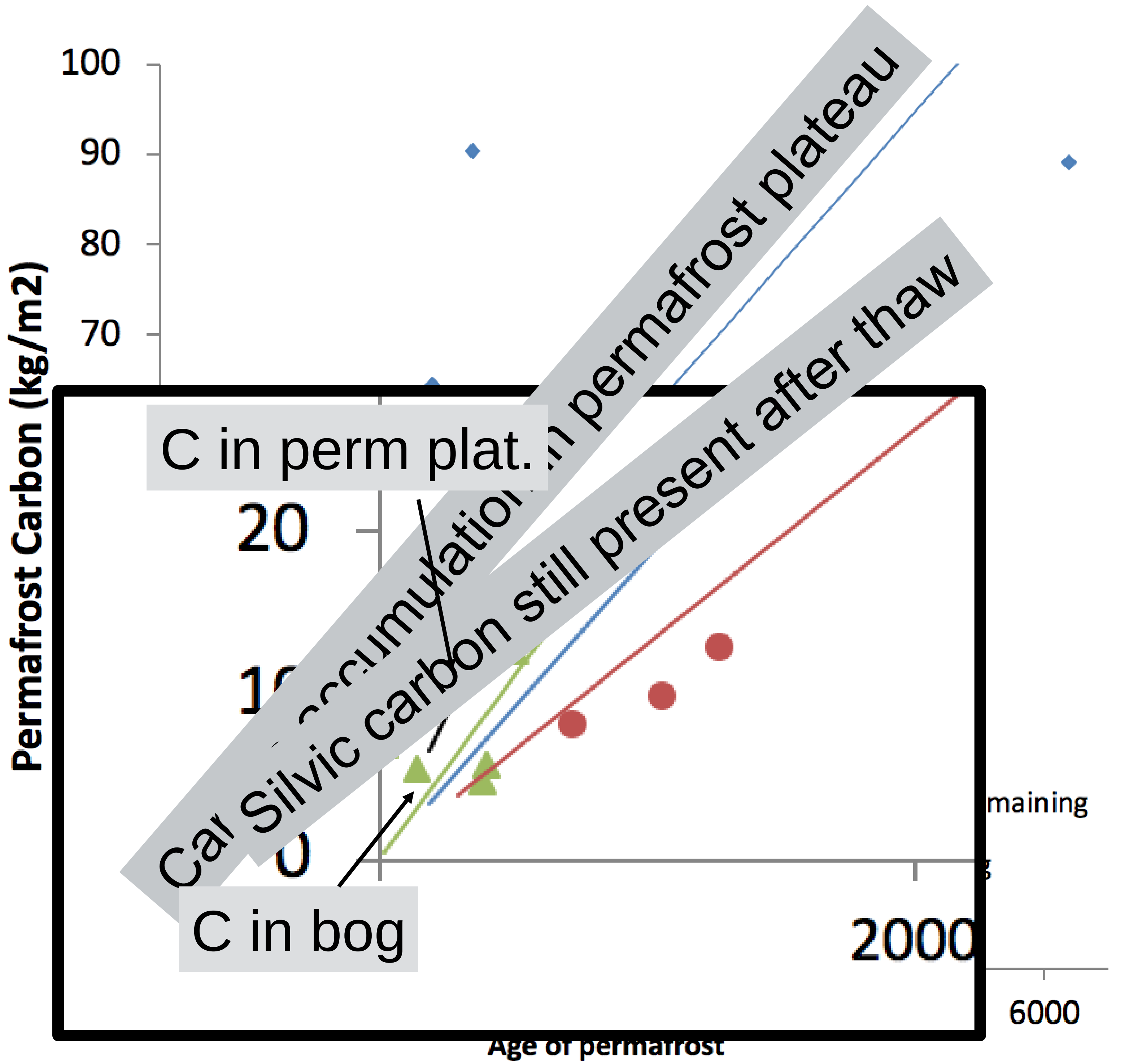
Incubation
CO_2 &CH_4 production
QPCR

Process modeling



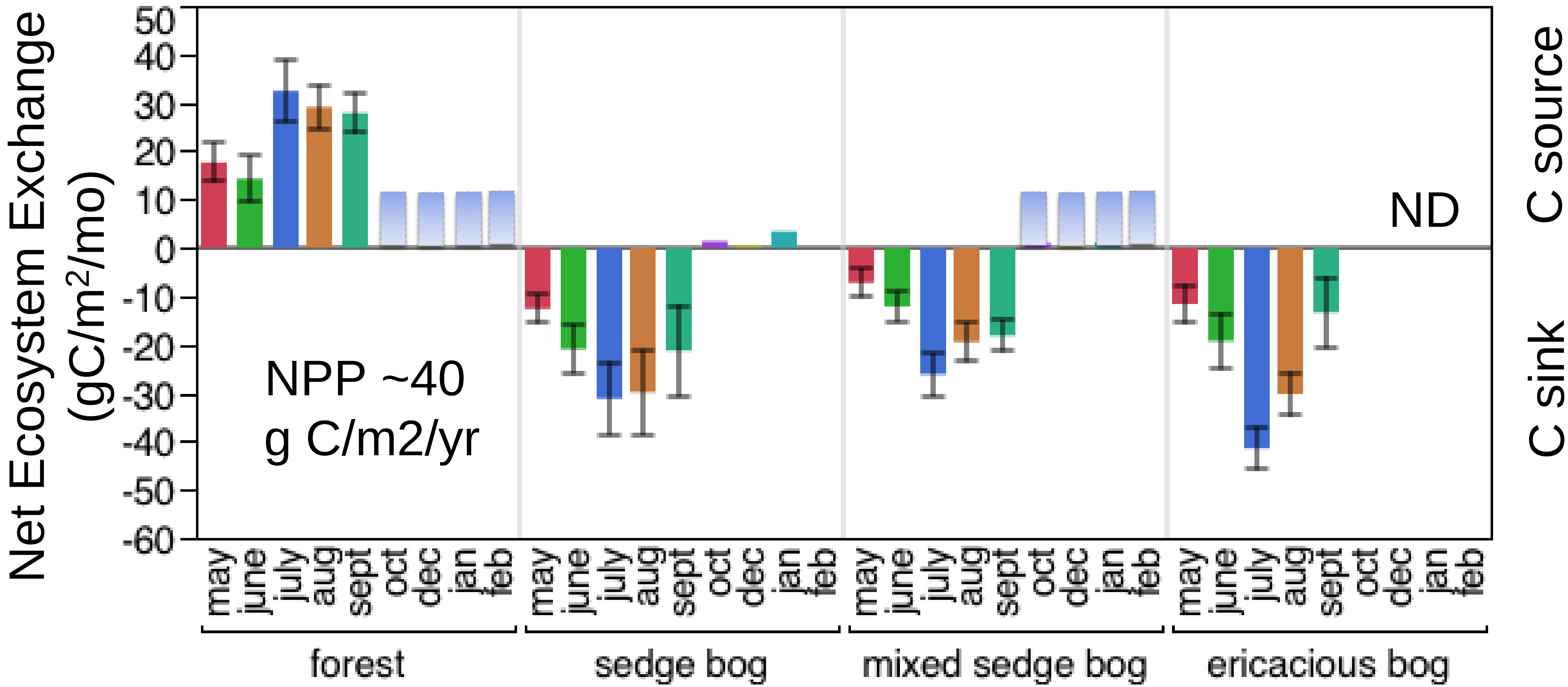
Peepers
Water chemistry
Isotopes
CH_4 and CO_2

Difficult to determine loss of C at BNZ due to young age of permafrost



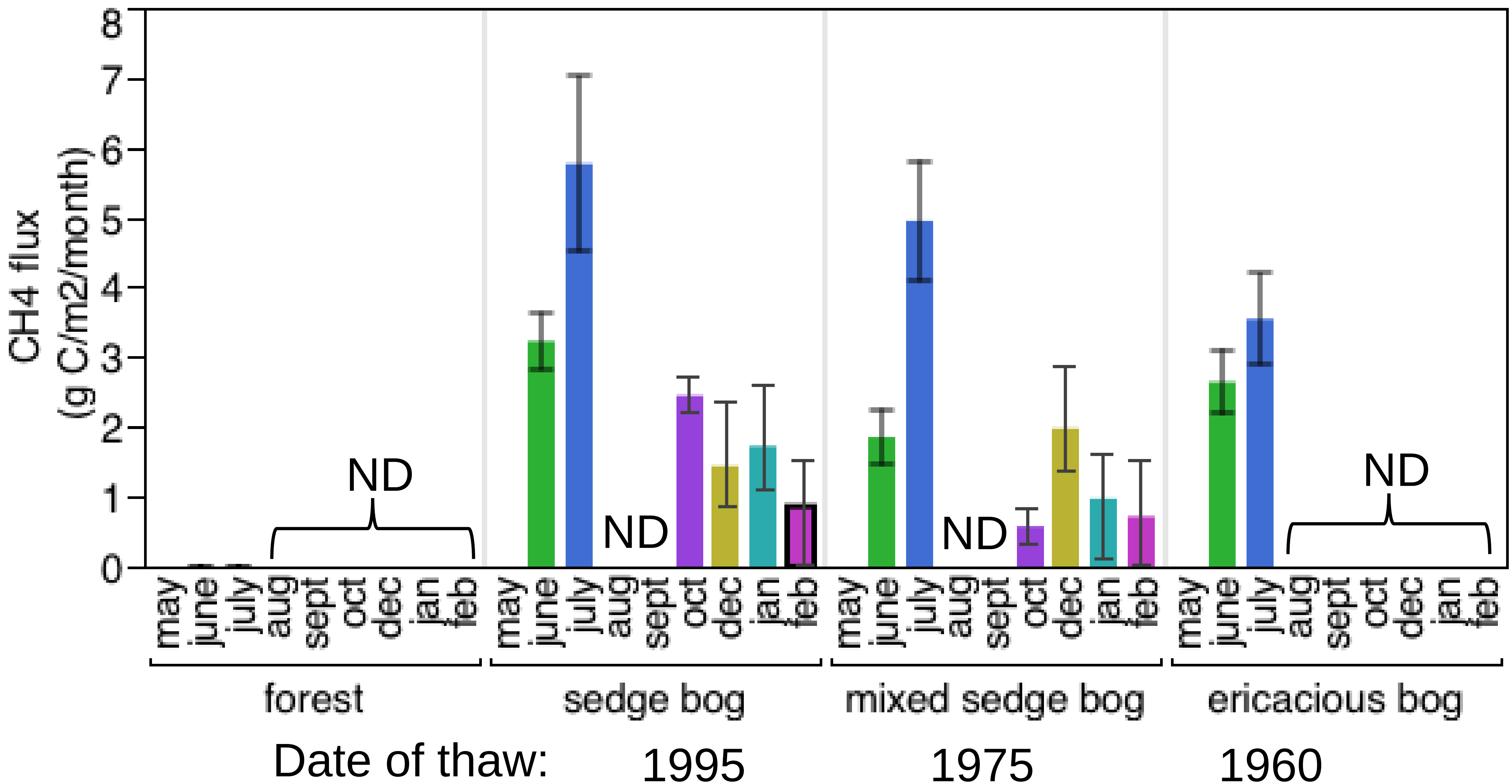
Bogs remain net sinks of C; Forest a source?

winter fluxes contribute significantly to overall C balance
Low productivity permafrost plateau
at edge of bogs could be sources of C



Date of thaw: 1995 1975 1960

- No difference in CH_4 fluxes among the bogs
-Wintertime contributions are significant



Pause and reflect

1. Changes in carbon stocks with thaw difficult due to the age of permafrost

2. Bogs do not lose large quantities of C, but wintertime fluxes contribute to a more C neutral state

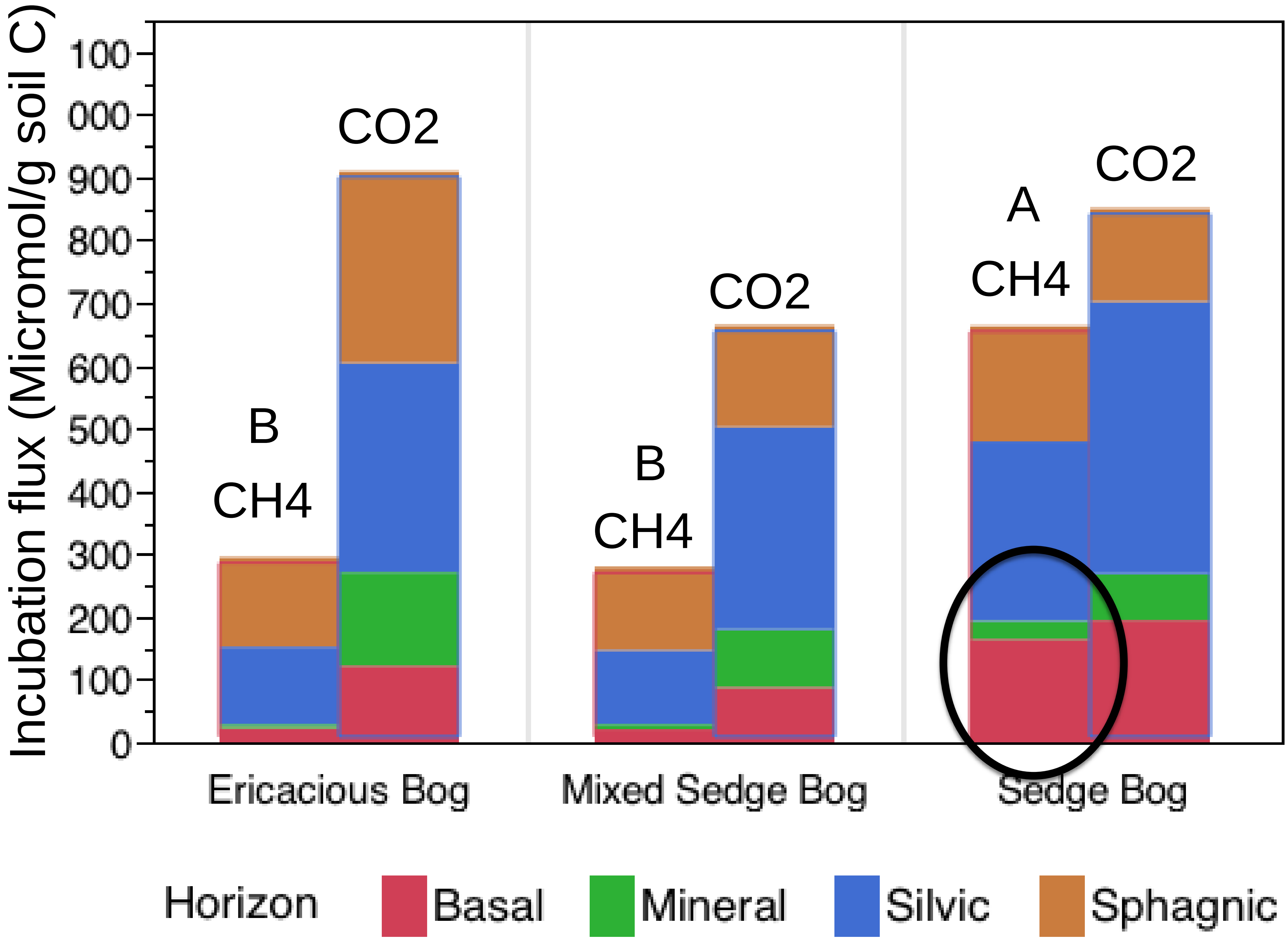
3. Near edge peatland plateau may be a C source

Though there are no observed differences in surface fluxes with bog age, how do microbial communities see it?

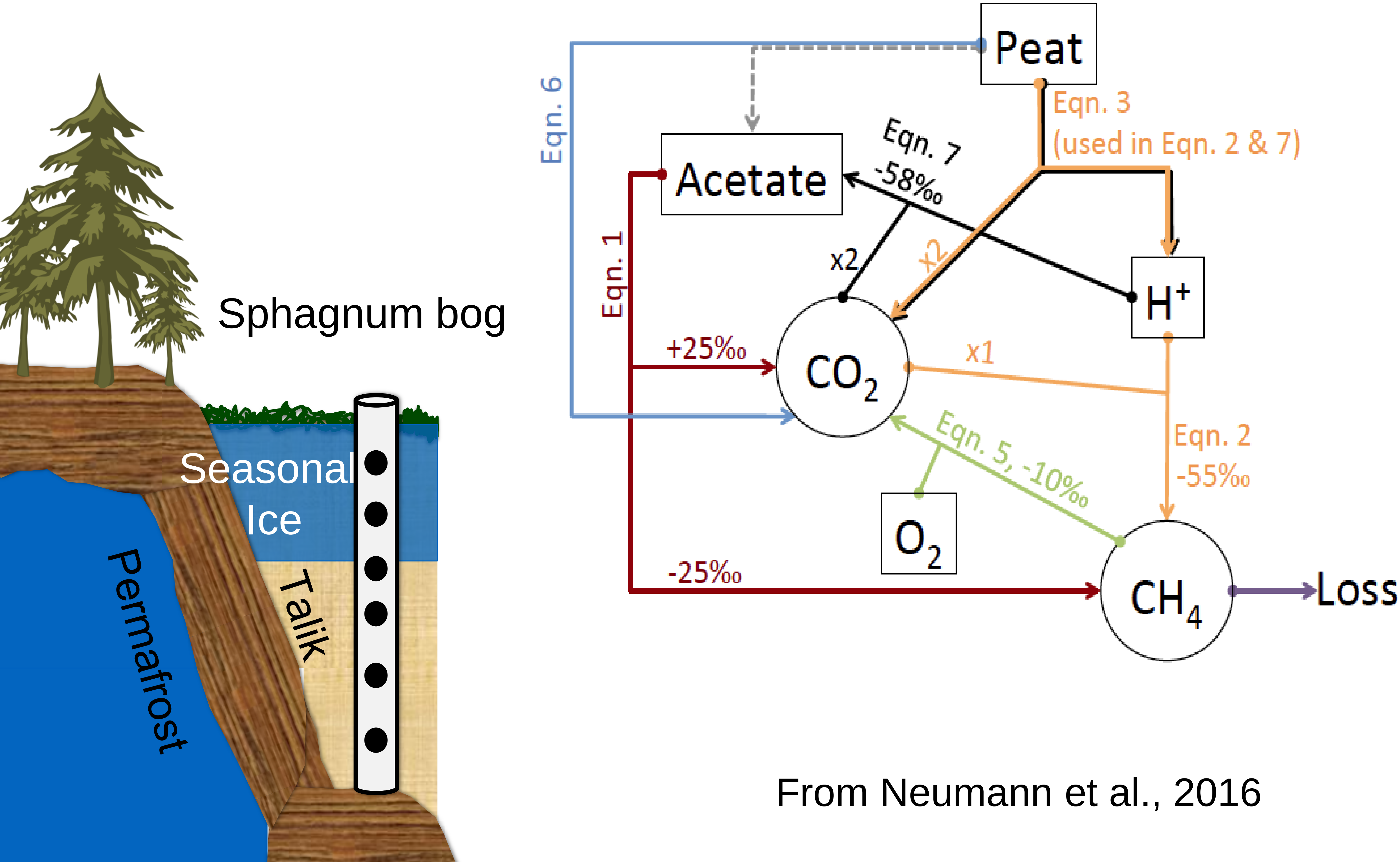
Cumulative CH_4 flux highest in sedge bog

(6 mo incubation)

Significant site effect and horizon effect



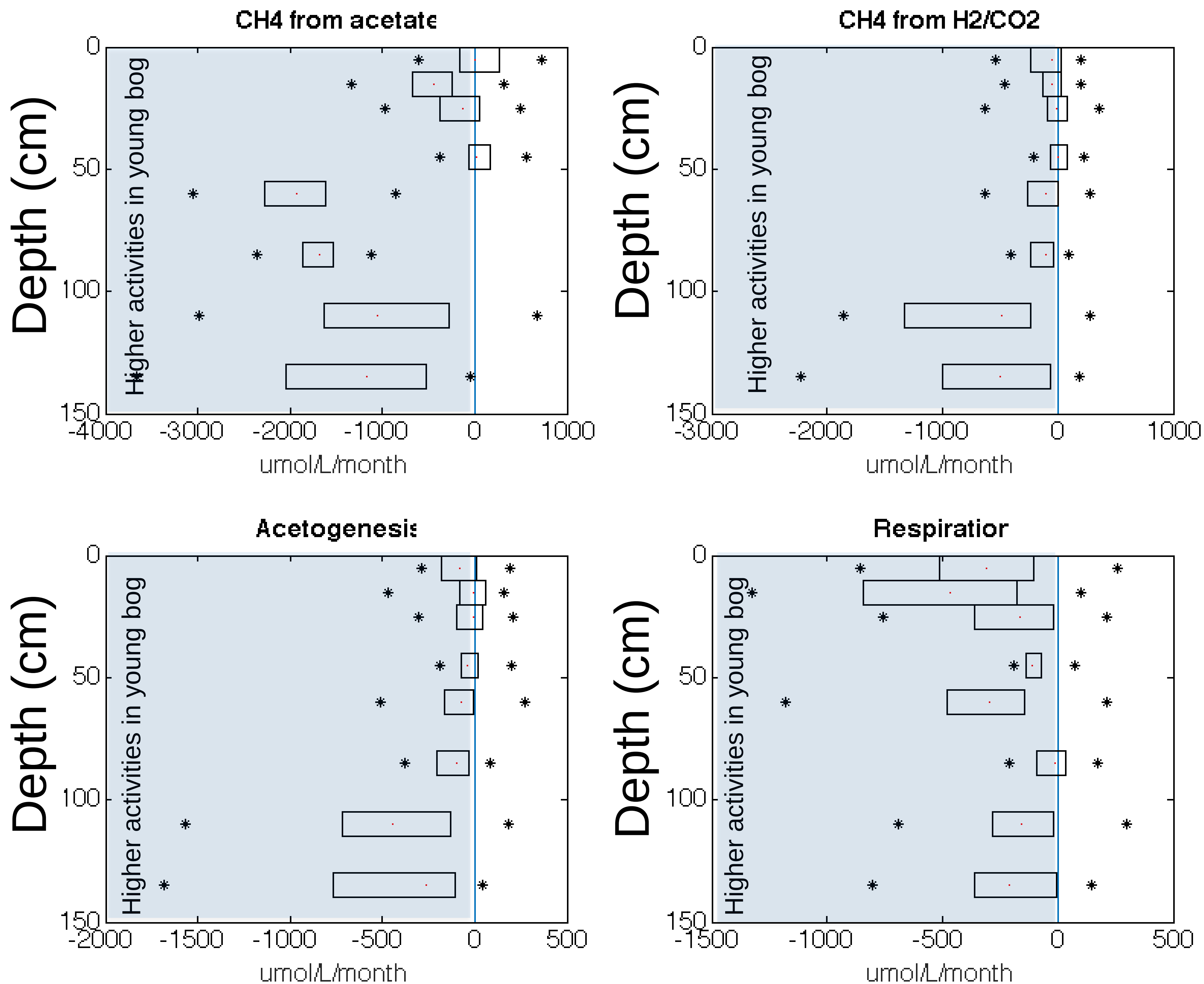
Model of microbial respiration, methanogenesis, acetogenesis based on porewater isotopes and dissolved gas concentrations



From Neumann et al., 2016

Porewater model indicates higher microbial activities deep within the youngest bog

Subtracting young bog rates from oldest bog rates



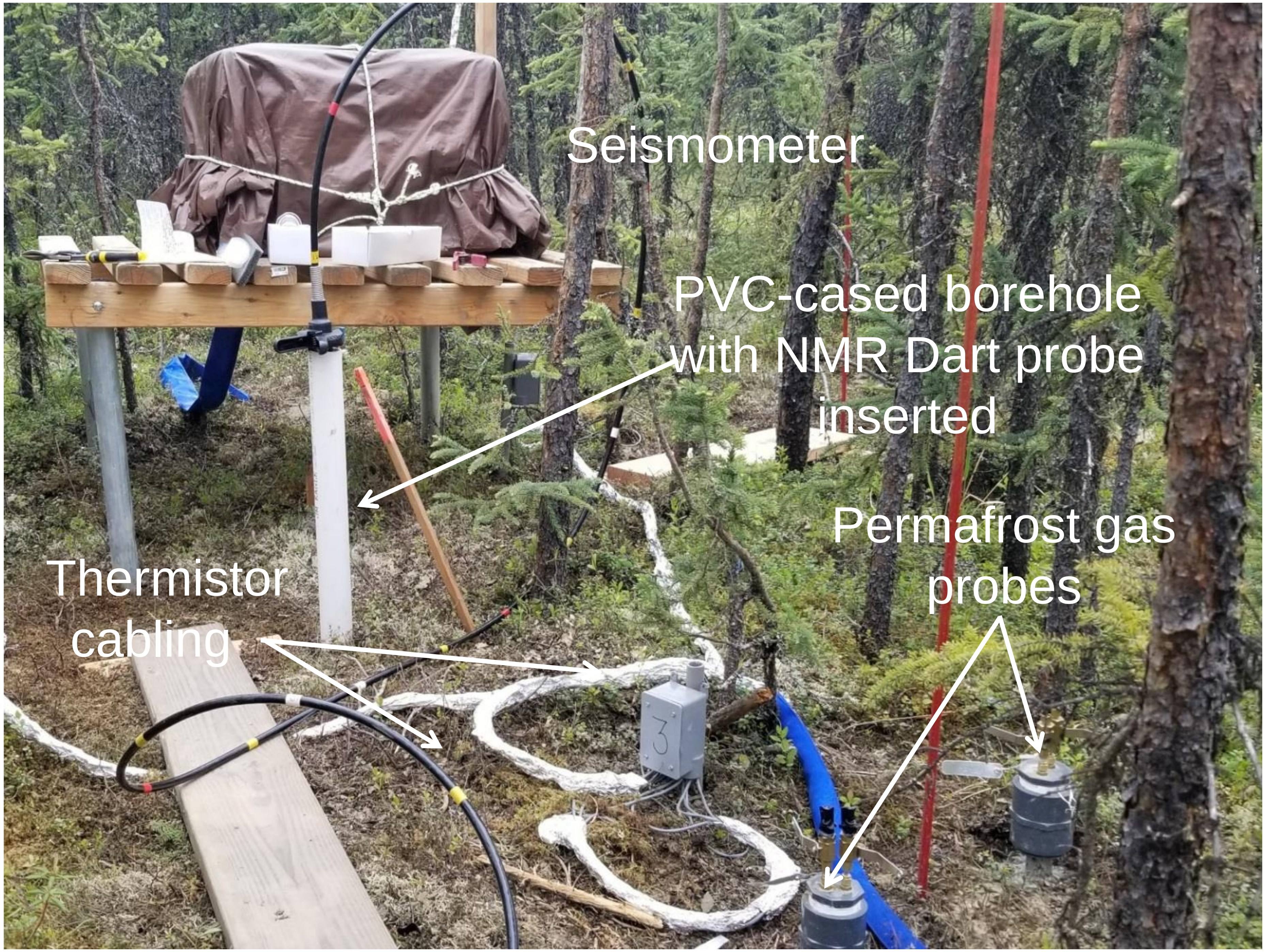

Summertime is nice, but..

Justification: We observe important losses of C in winter, and possibly in the permafrost plateau prior to collapse

Do we observe changes available water and microbial activities as permafrost slightly warms (e.g. -0.8C to -0.2C)?

Could activity in ice contribute to important carbon losses?

How we measure in situ physical and biogeochemical properties of permafrost



In Situ NMR
Sensing of water content of permafrost

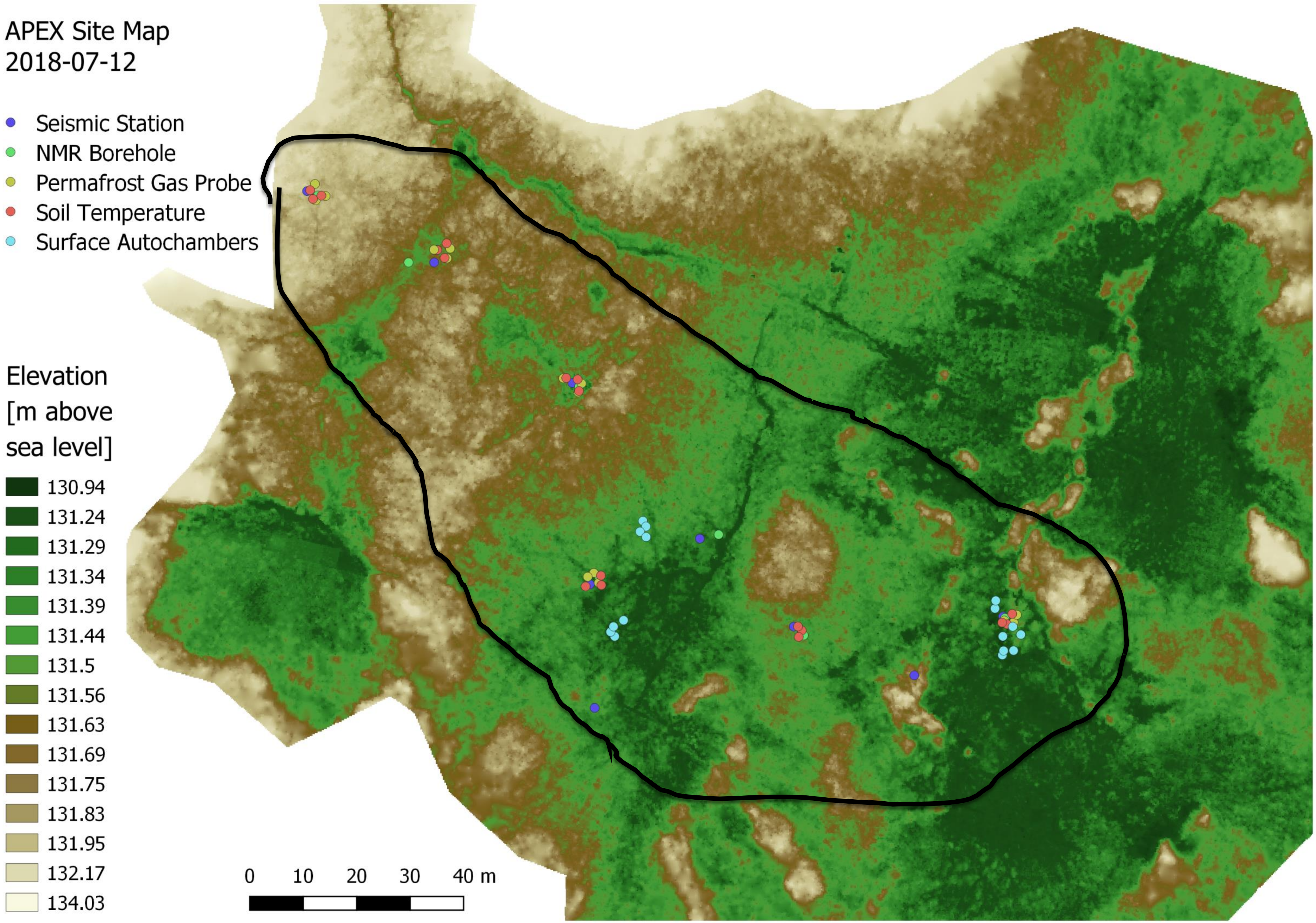
Thermistors
Temperature arrays down to 2.5m

Permafrost gas probe
CO2, CH4, and N20 gas concentrations

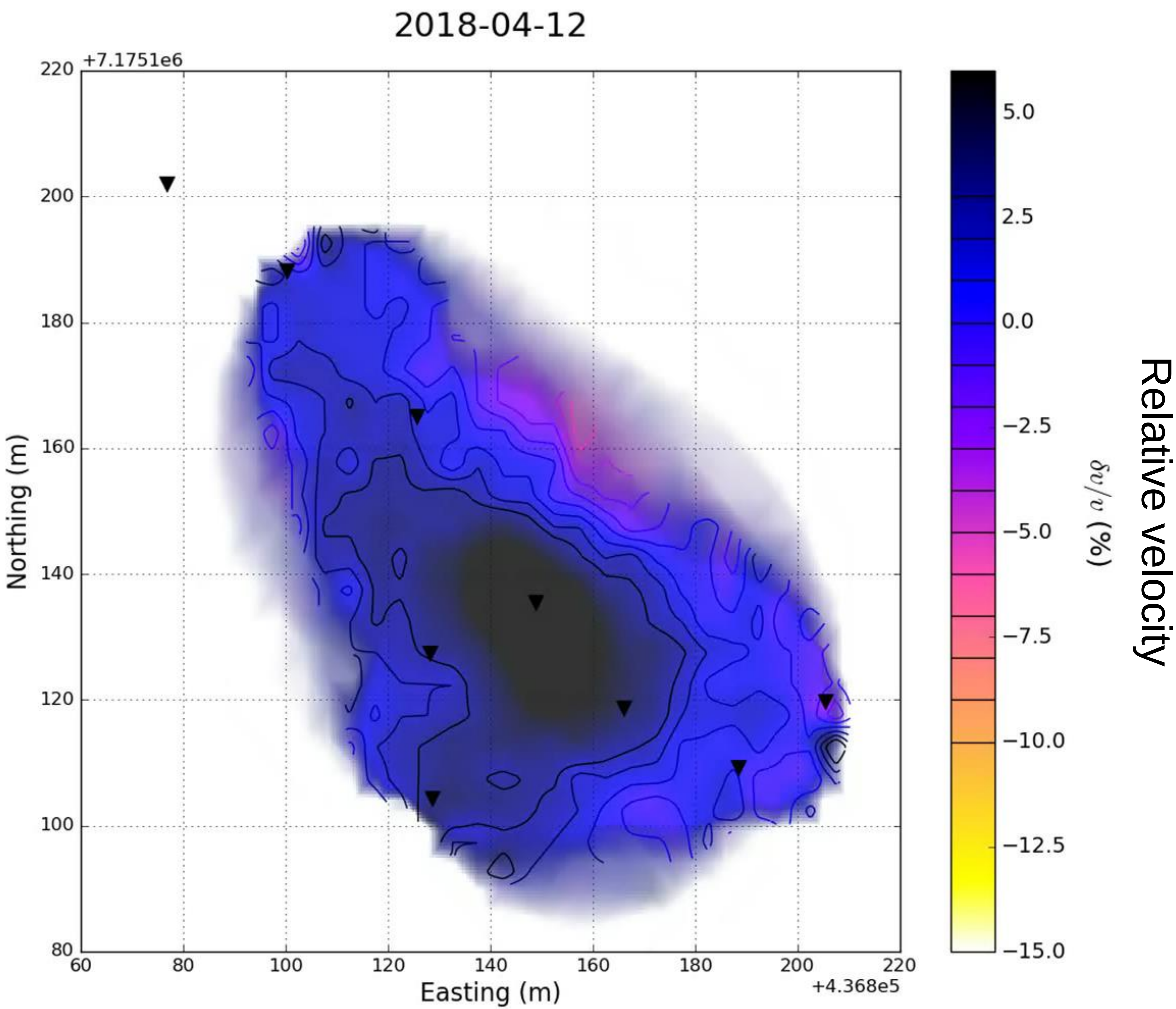
Broadband, 3-component (*xyz*) seismometer
seasonal changes in ice and water content

Autochamber system
Surface fluxes of CO_2/CH_4

Lidar Digital Elevation Model

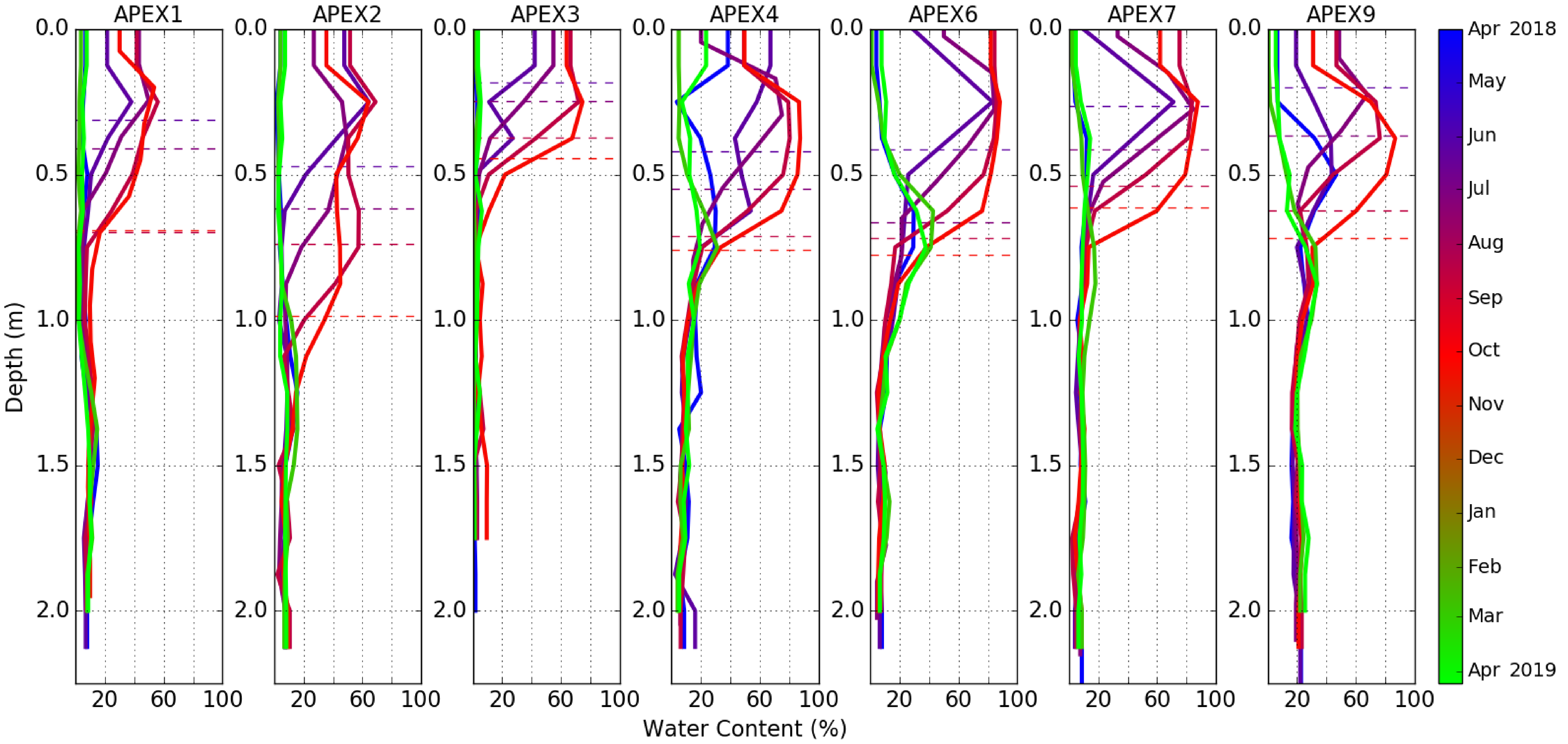


Credit: Ronnie Daanen



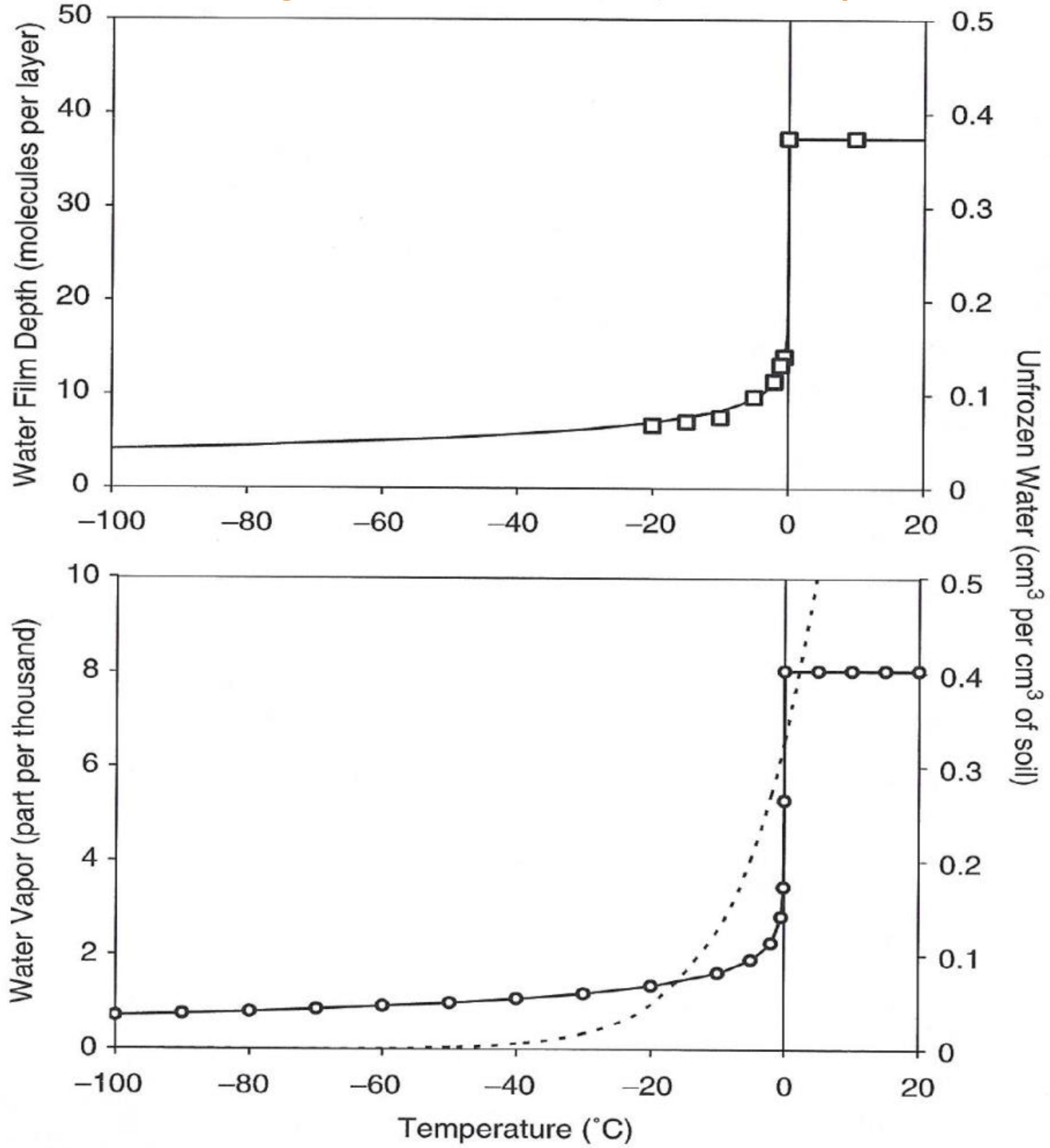
2018-04-12
+7.1751e6
Northing (m)
220
200
180
160
140
120
100
80
60
80
100
120
140
160
180
200
220
Easting (m)
+4.368e5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
−12.5
−15.0
δv/v (%)
Relative velocity

Along this gradient, soil temperatures and soil moisture increase *within intact permafrost*



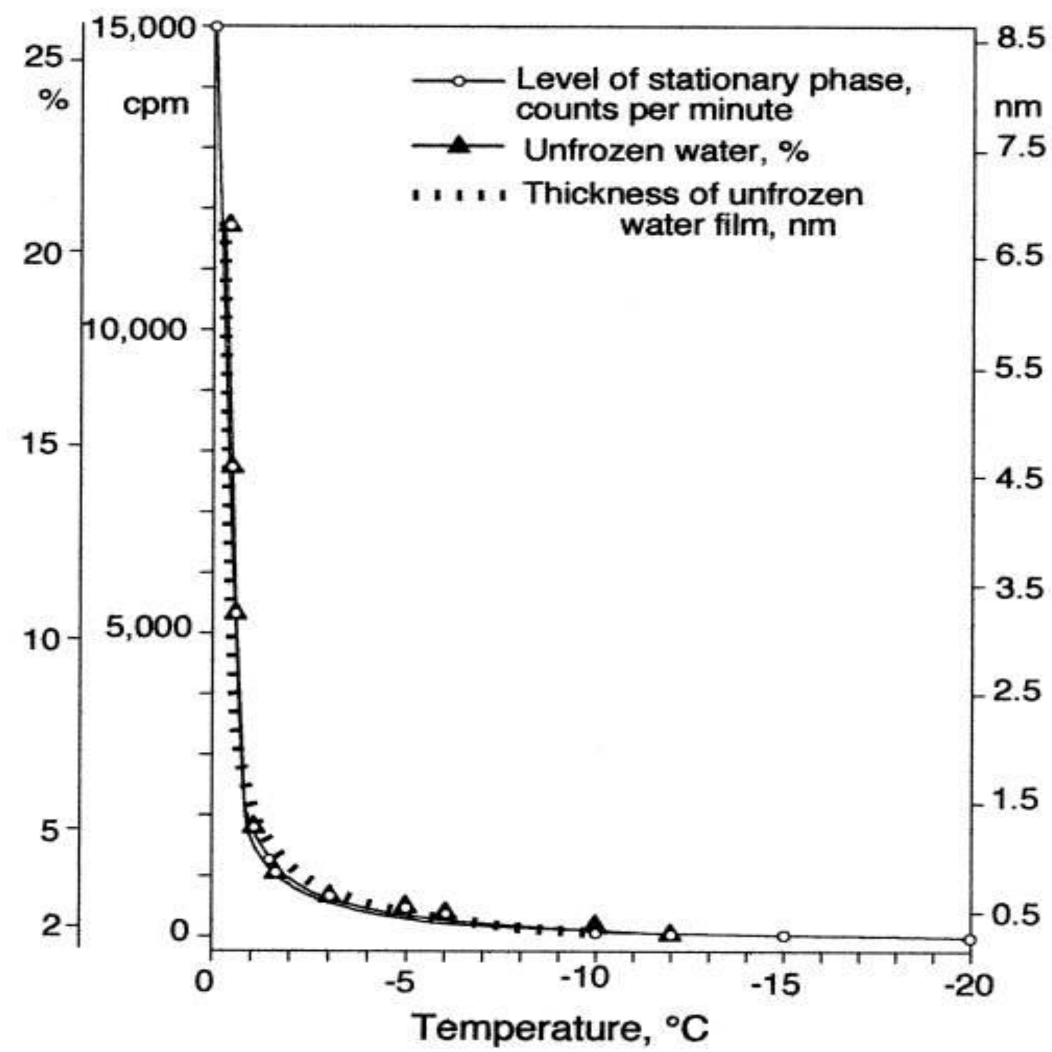
Why is this important:
As you approach thaw there are exponential increases in water availability and microbial activity

Increasing unfrozen water with temp



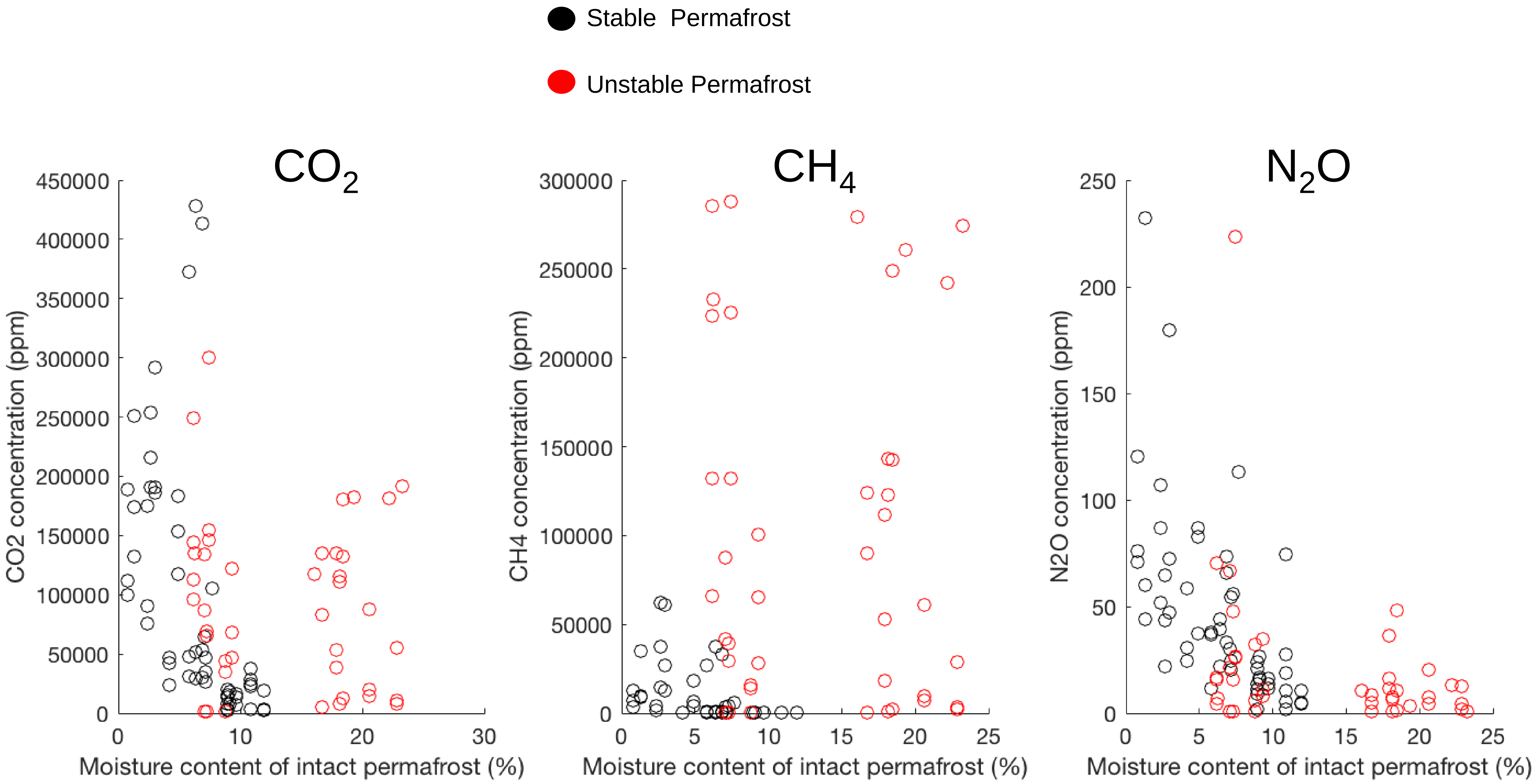
Romanovsky and Osterkamp 2000 *Permafrost Periglac Process* 11:219

Increasing microbial activity with temp

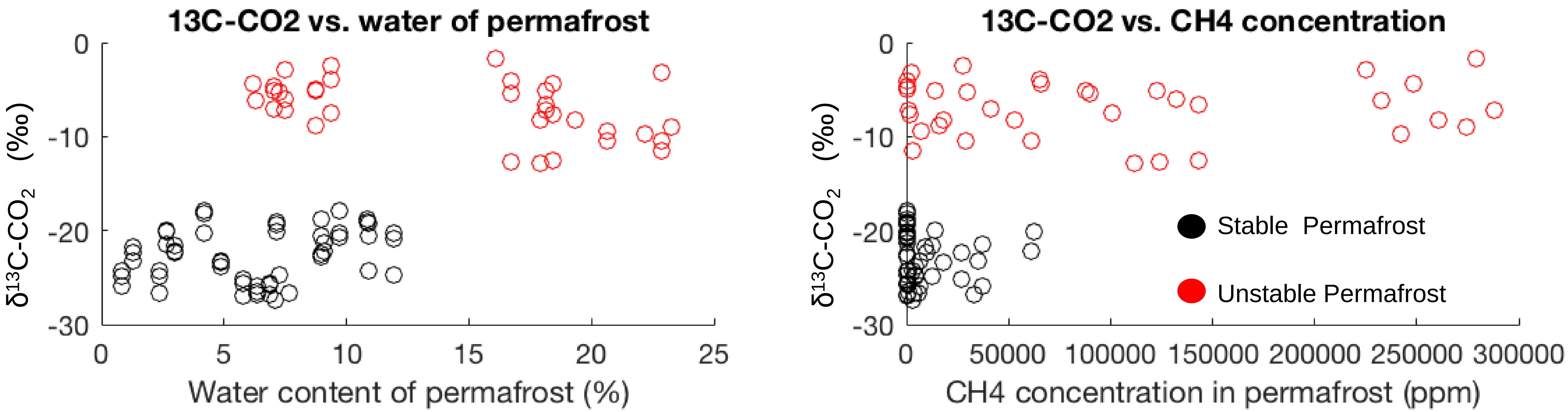


Rivkina et al. 2000 *AEM* 66:3230

Changes in gas concentrations in permafrost approaching thaw



^{13}C-CO_2 becomes very enriched in 'unstable permafrost', potentially indicating CO_2 reduction to methane

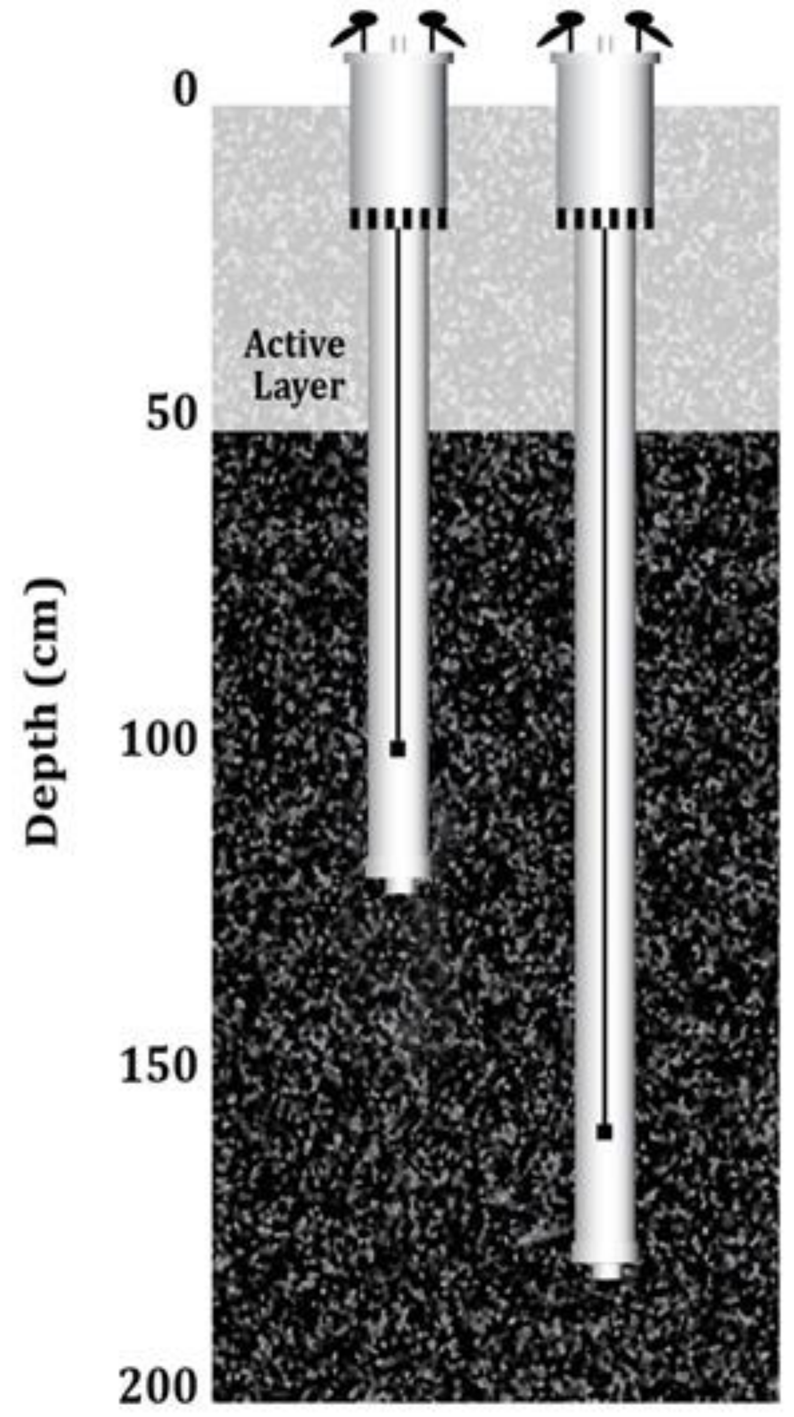


Do these high gas concentrations translate into significant fluxes to the active layer?

Short answer: We do not know yet

Diffusion of gases through permafrost a major unknown

We are just beginning to measure the diffusion rate of gases through ‘warm’ permafrost



Analogously: Fluxes through surface ice

Eosense forced diffusion chamber:

Fluxes on the order of 15g C/m2/month

Conclusions

Carbon may be lost following permafrost thaw at APEX, but it is very difficult to observe

Microbial activity increases as permafrost approaches thaw (< 0ºC), and soon after thaw: indicating the importance of this critical interface for carbon losses.

Ecosystem carbon losses seem tied to lowland black spruce at the edge of thaw, and wintertime processes.

Thank you

Alaska Colleagues

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UAF UNIVERSITY OF ALASKA FAIRBANKS

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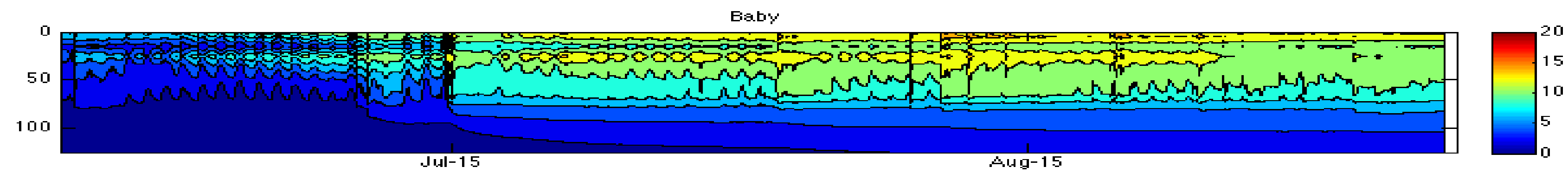
BONANZA CREEK LTER Boreal Forest Ecology

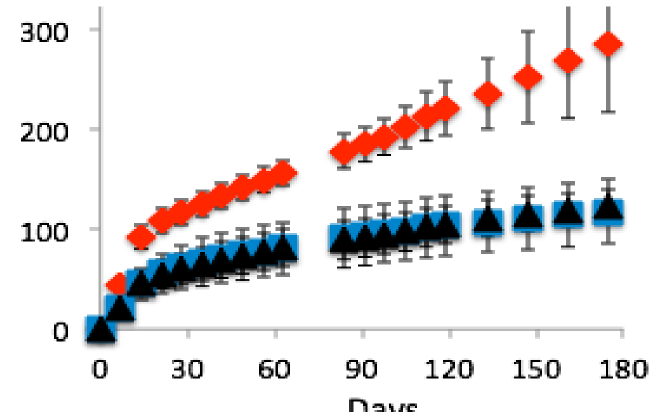
NSF

Mechanisms of increased CH_4 flux from very young bogs

- Temperature



- Microbial physiological potential

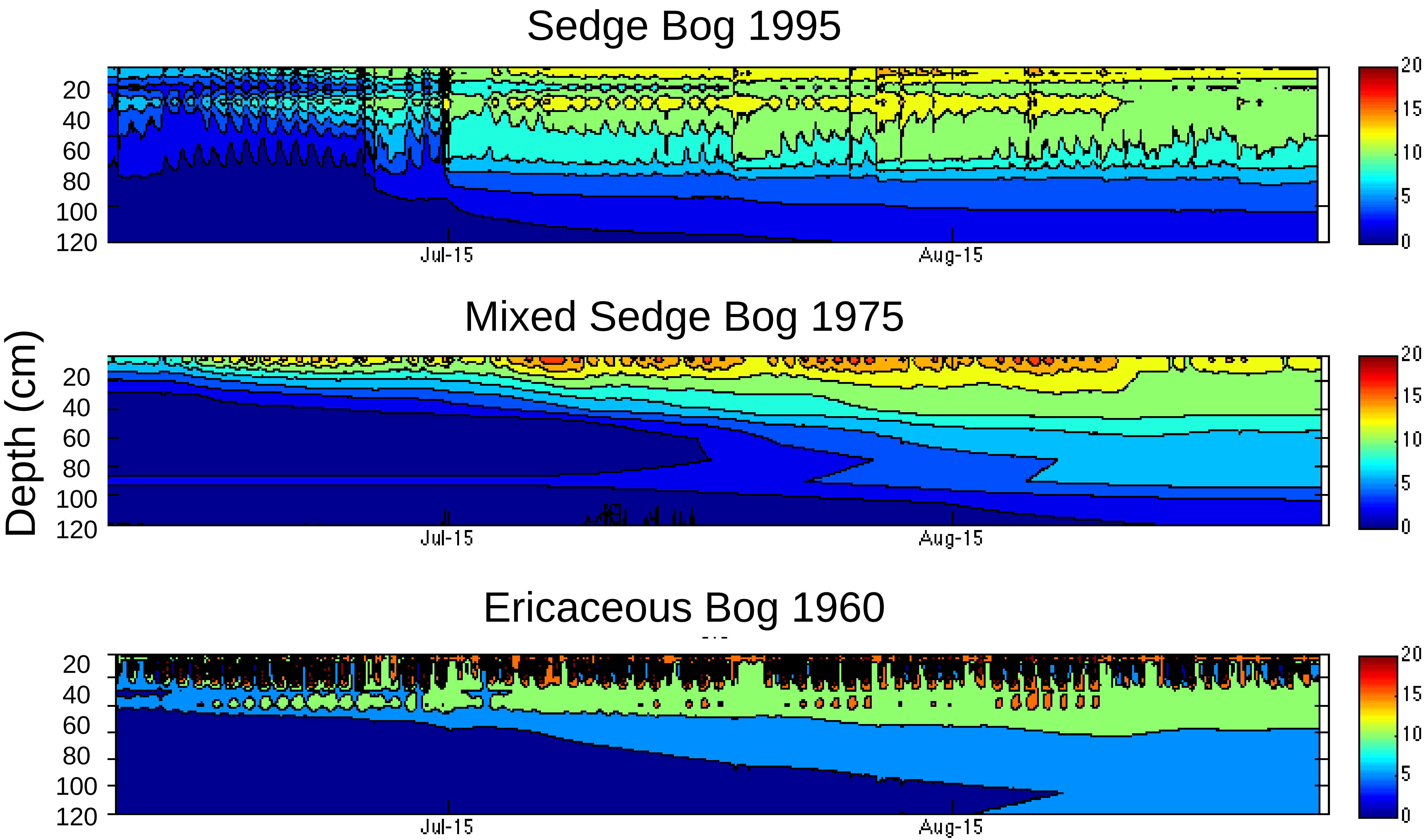


- Carbon chemical composition

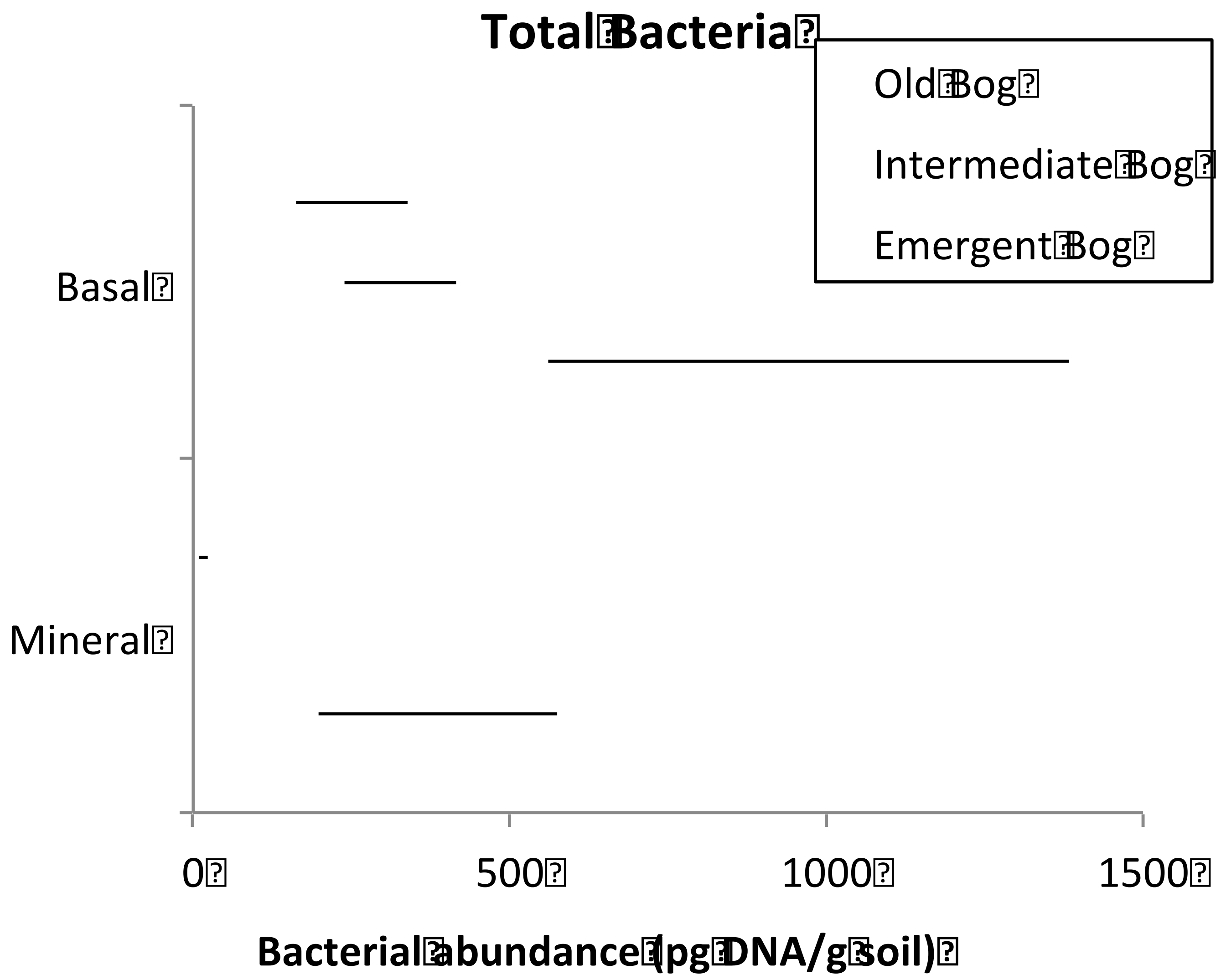
DOC, FTIR

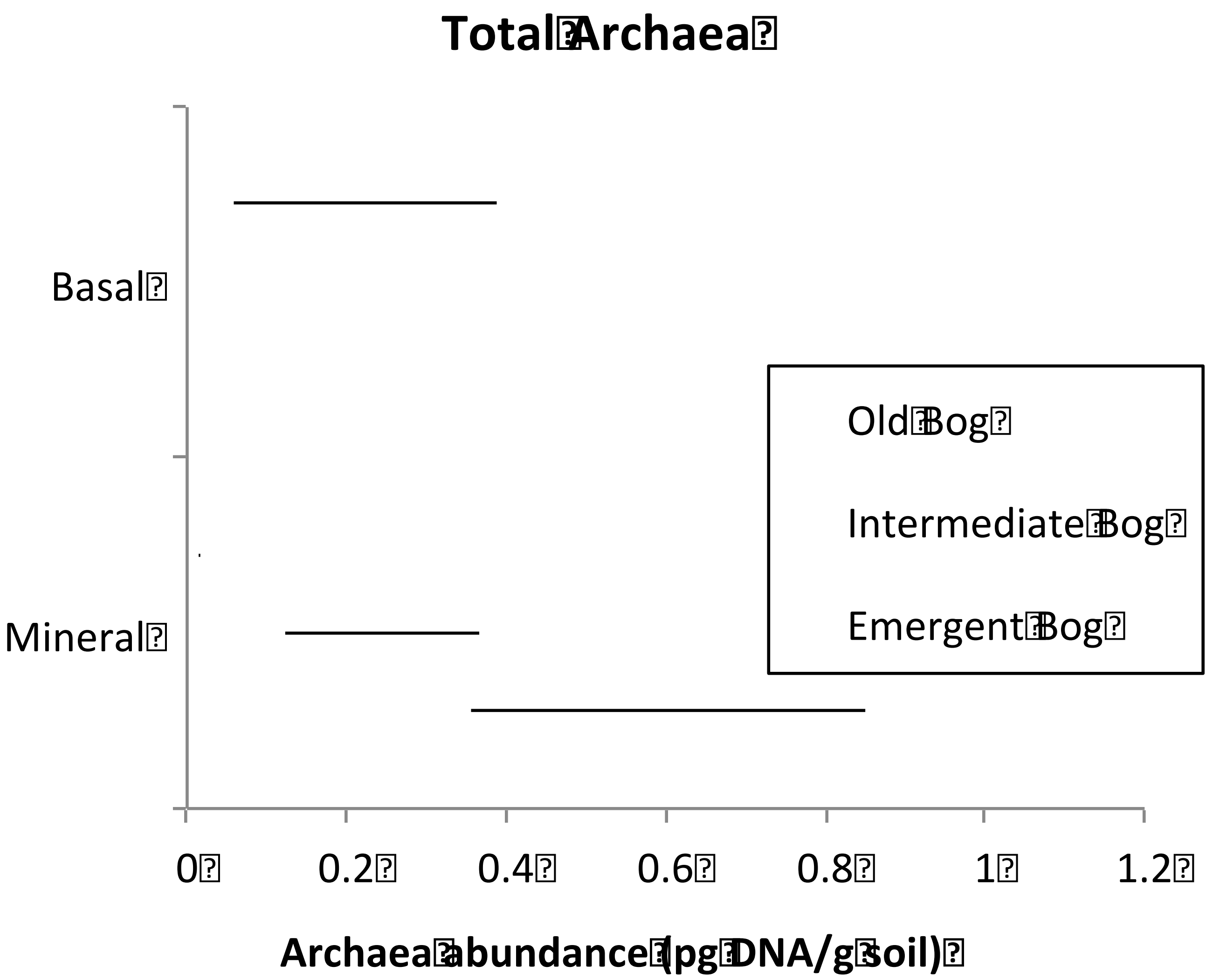
- Transport processes

Heat penetrates deeper into the youngest bog



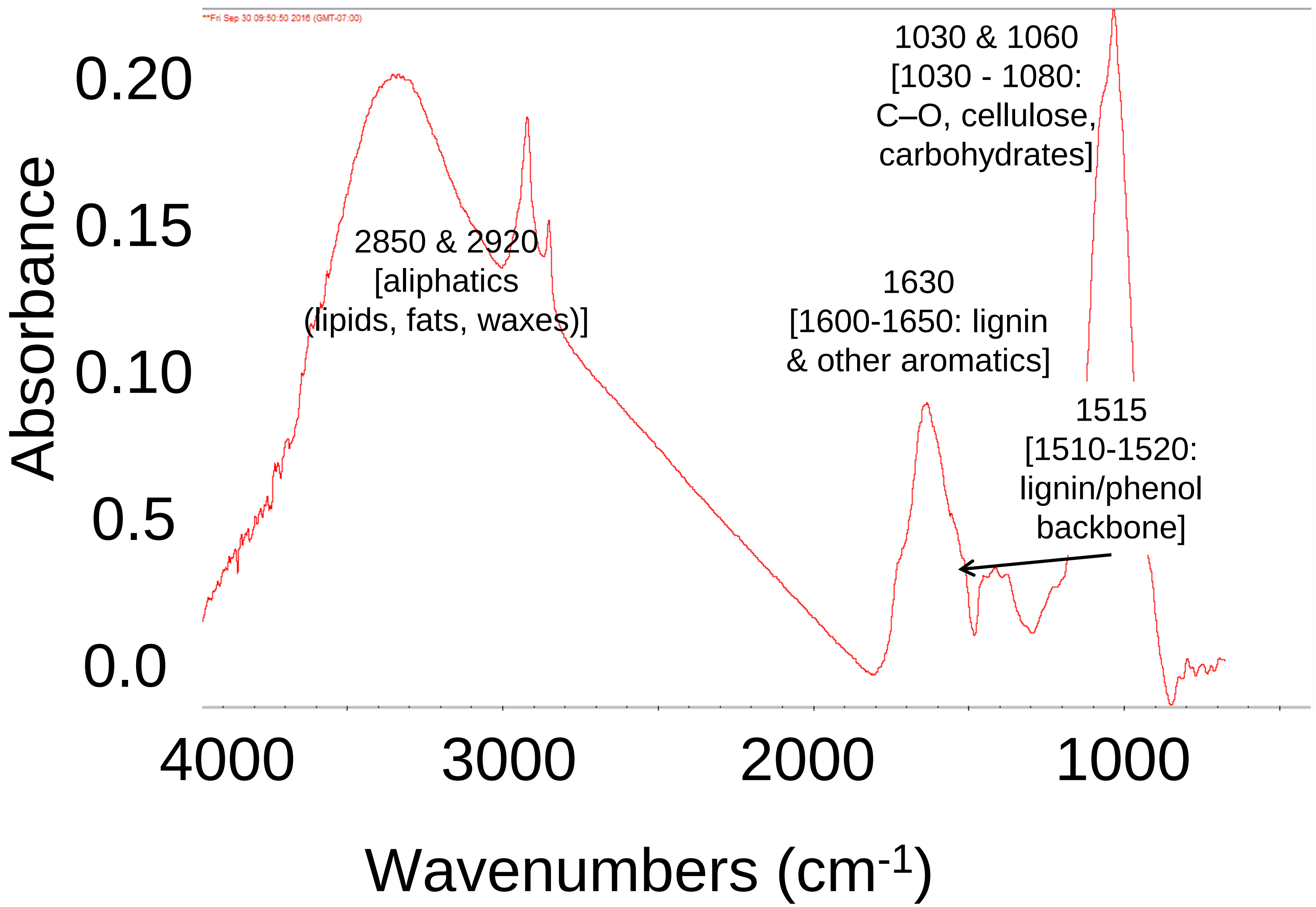
Greater bacterial (and possibly archaeal) abundance in youngest bogs





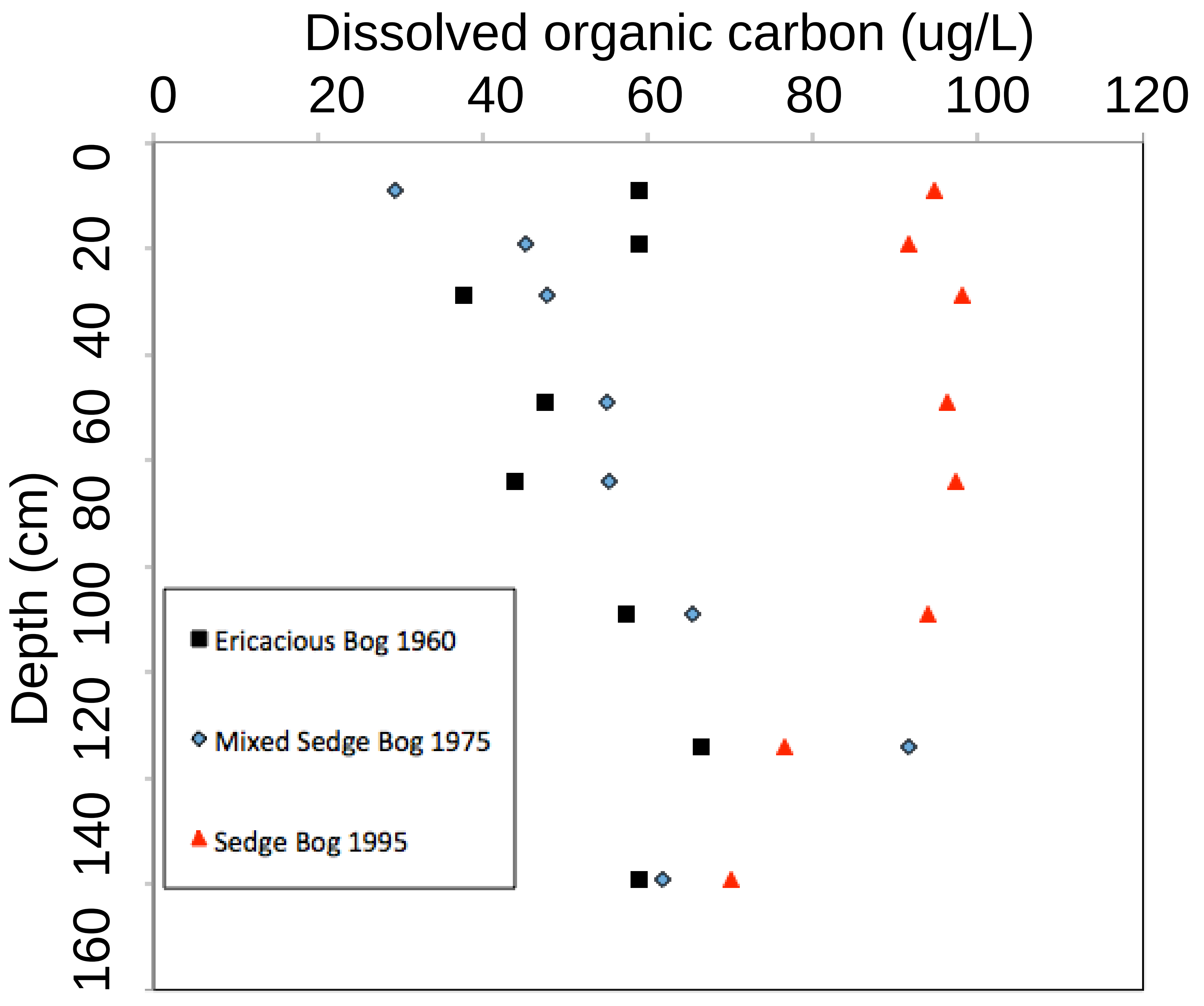
Are there differences in soil chemical composition? Sedge bog carbon is ‘less processed’

FTIR analysis of organic matter moieties



	Lignin/Cellulose 1515/1030 Mean
Sedge Bog	0.29 (.04)[a]
Mixed Sedge Bog	0.23 (.03)[b]
Ericacious Bog	0.21 (.04)[b]
Sphagnic	0.24 (.03)[ab]
Silvic	0.30 (.02)[a]
Basal	0.20 (.03) [b]

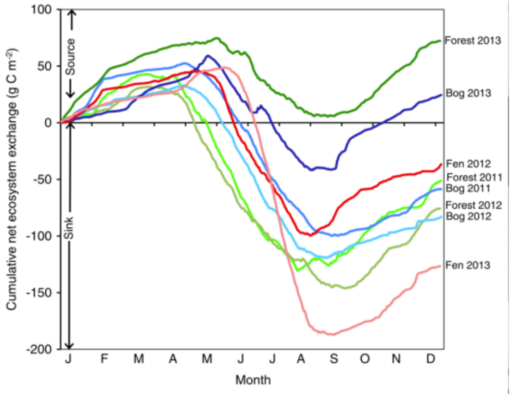
Twice as much dissolved organic carbon in the young sedge bog



C cycle studies – mostly during ‘active’ season

Short summer ‘active’ season

Cold season (8-10 months)

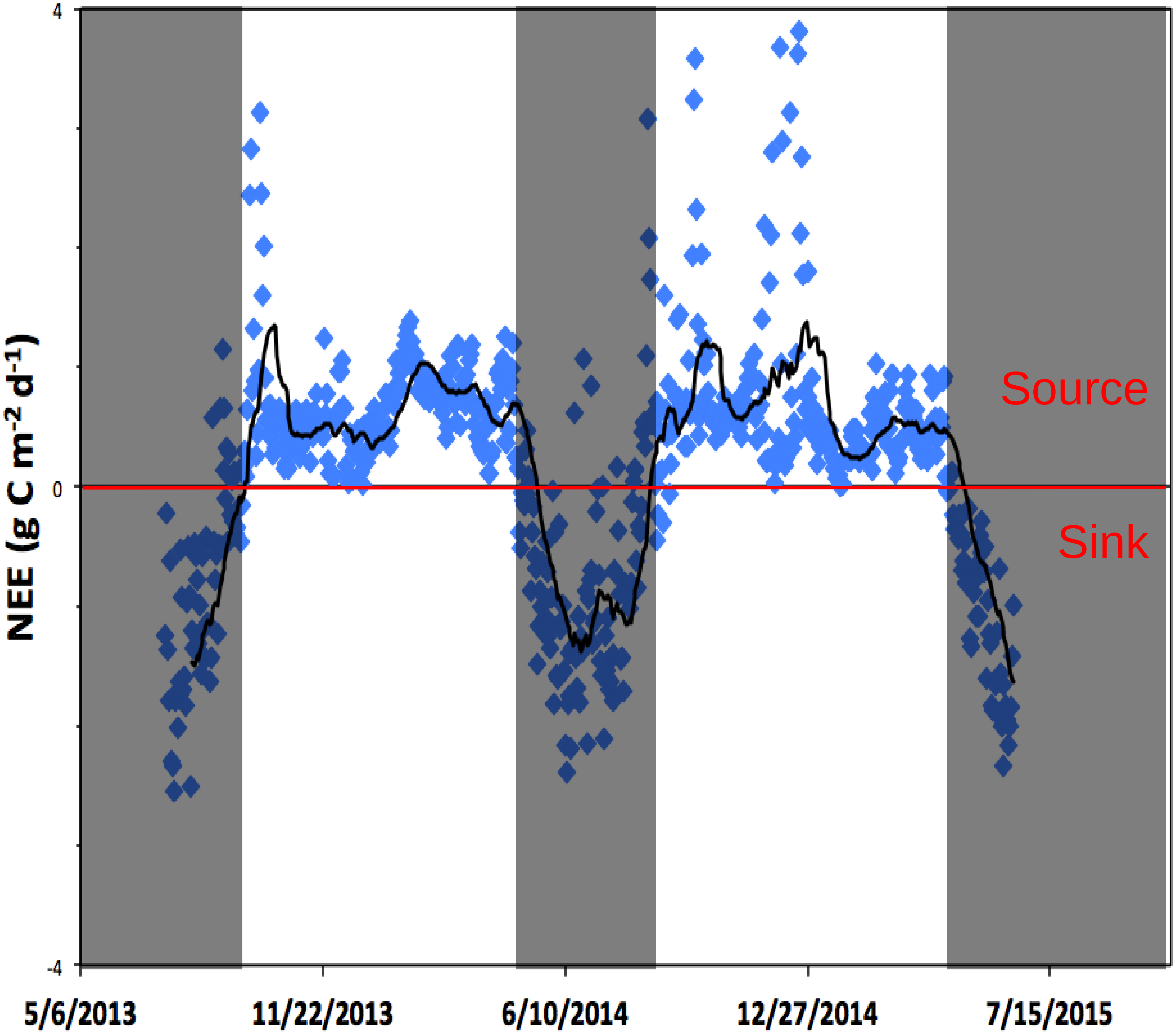


Euskirchen et al. 2014 JGR Biogeosci

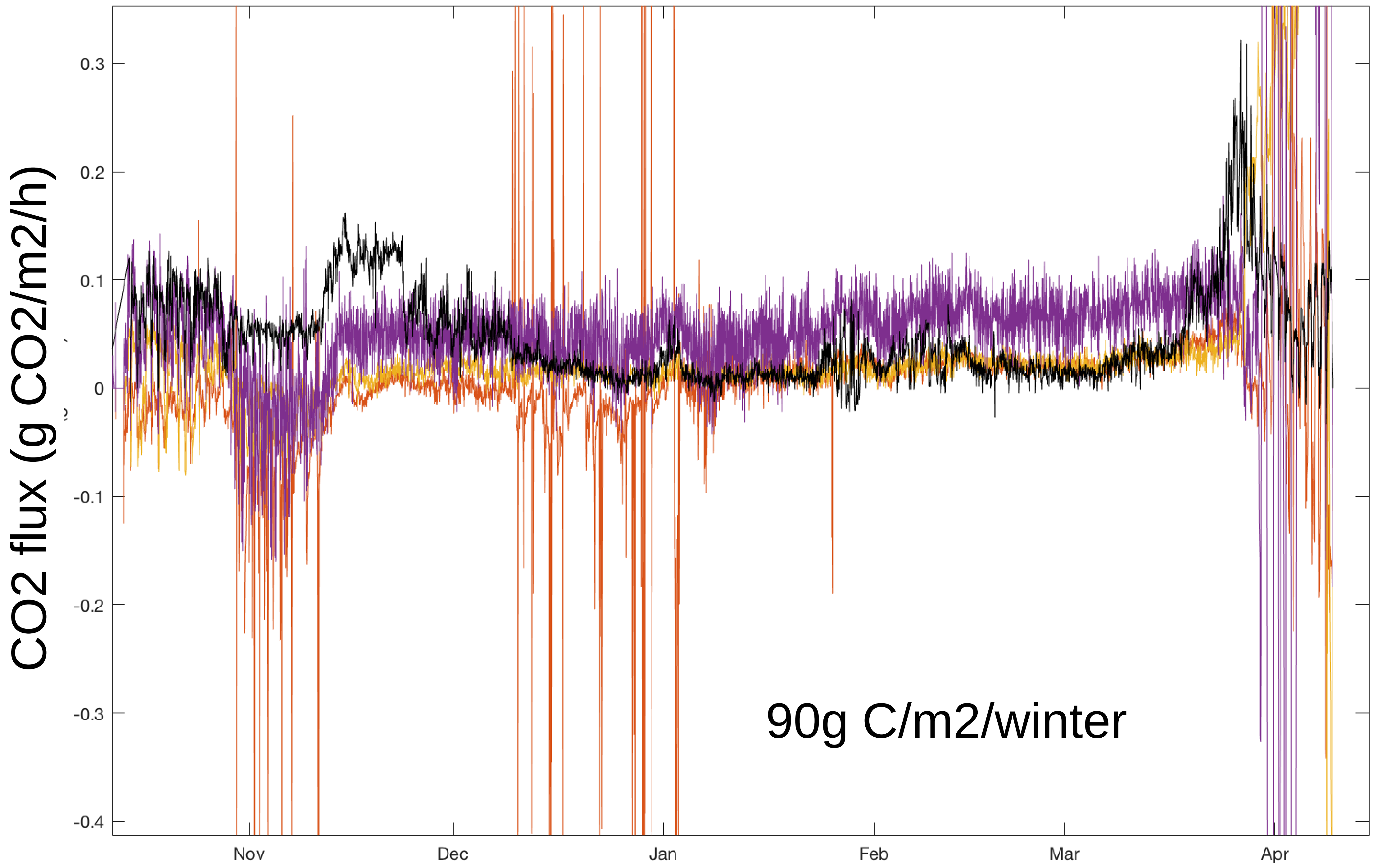
- ➢ Flux chamber, tower, and satellite data have shown significant CO_2 release during winter

Net

Eddy Covar



Hot off the presses: Winter CO_2 fluxes (Eosense)



Extreme Gradients of GHG Gases in Both Stable and Unstable Permafrost

Stable Permafrost

Unstable Permafrost