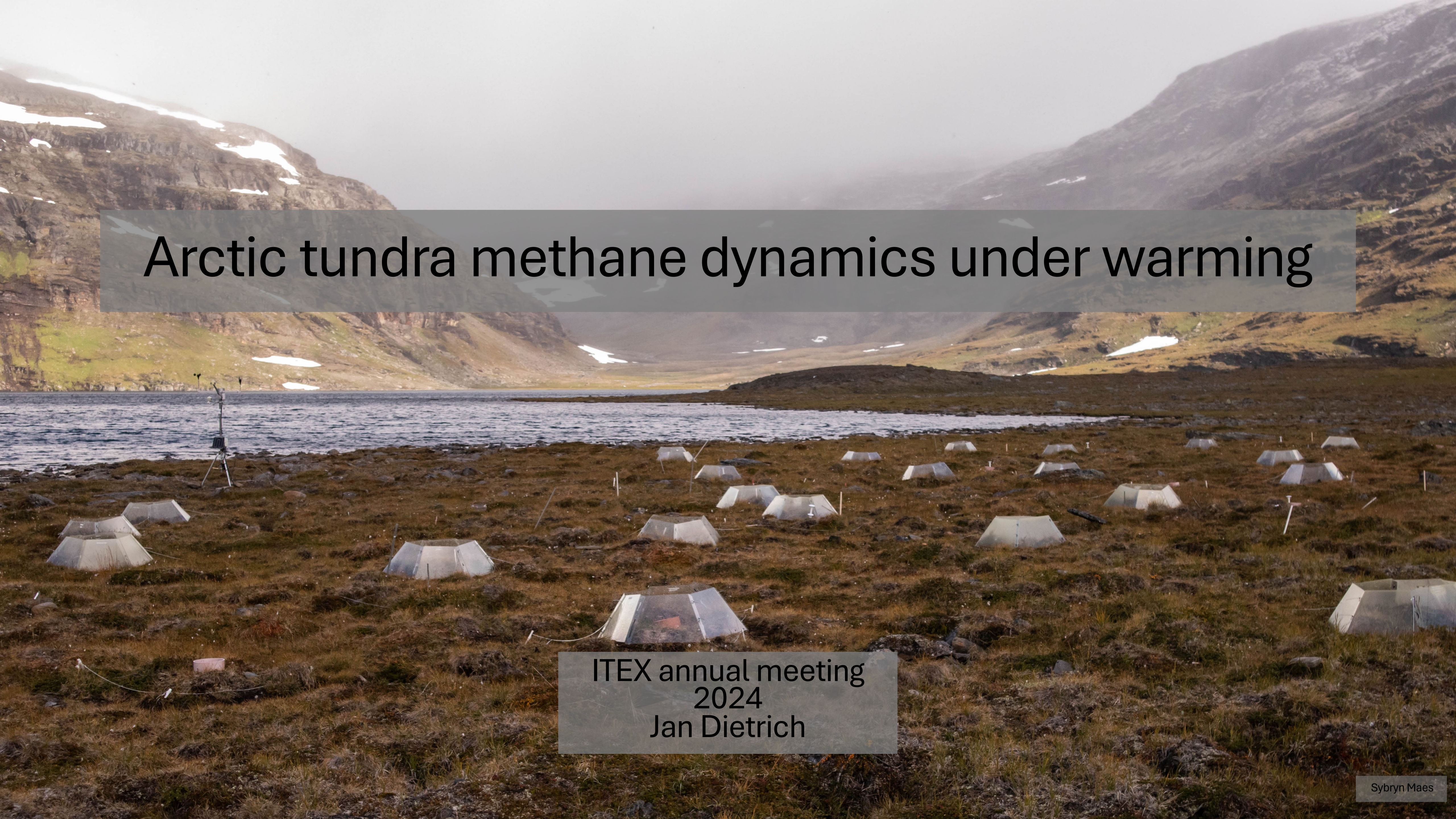
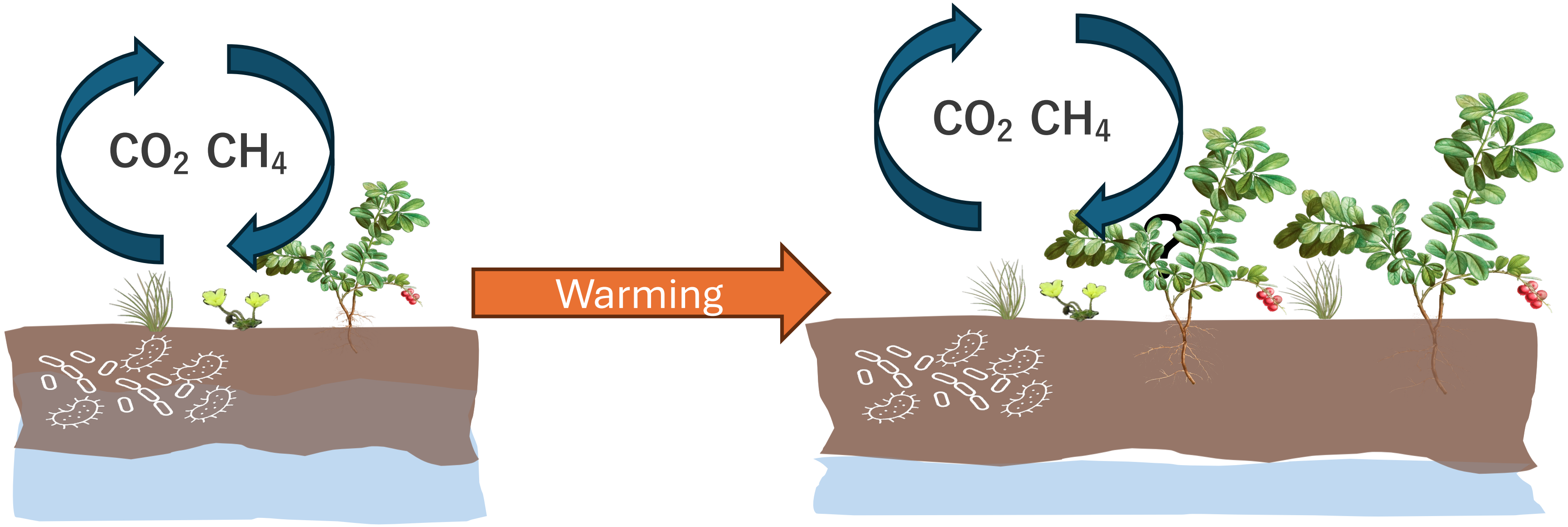

Arctic tundra methane dynamics under warming
ITEX annual meeting
2024
Jan Dietrich
Sybryn Maes

Climate change in the tundra

How does the carbon cycle in tundra ecosystems respond to a rapidly warming climate?

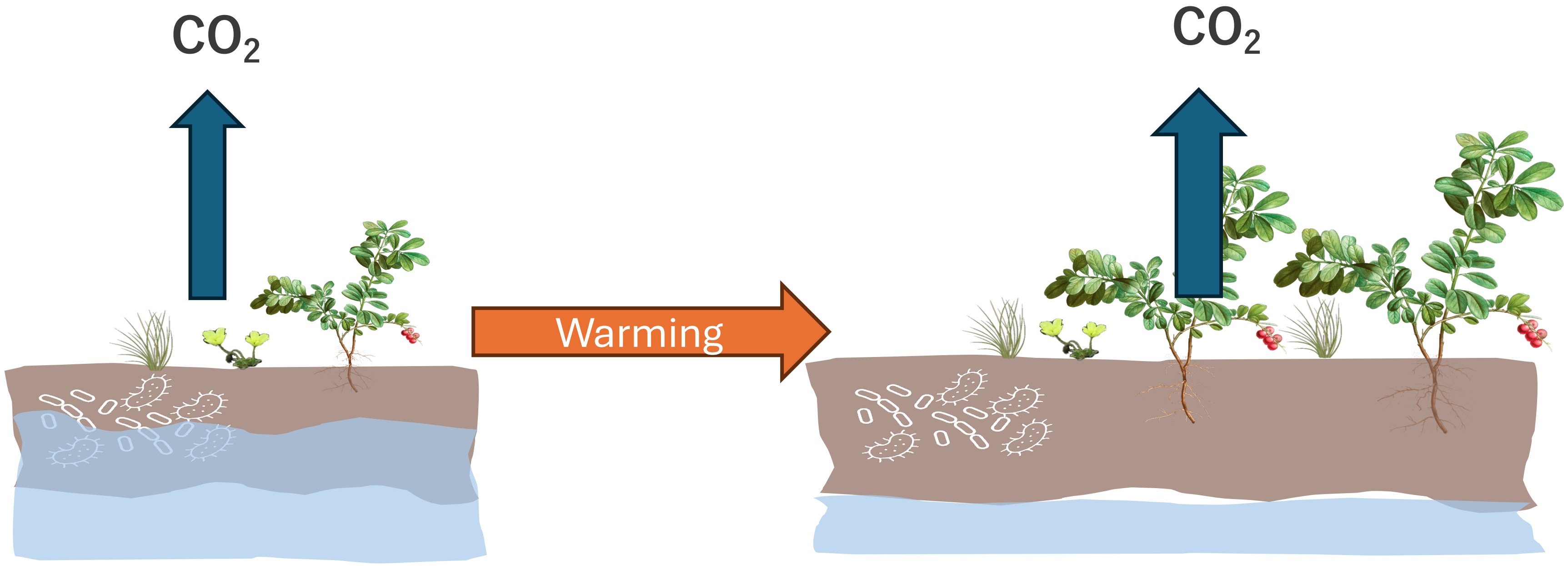


Carbon Cycling CO2

Ecosystem respiration responses to warming across the tundra

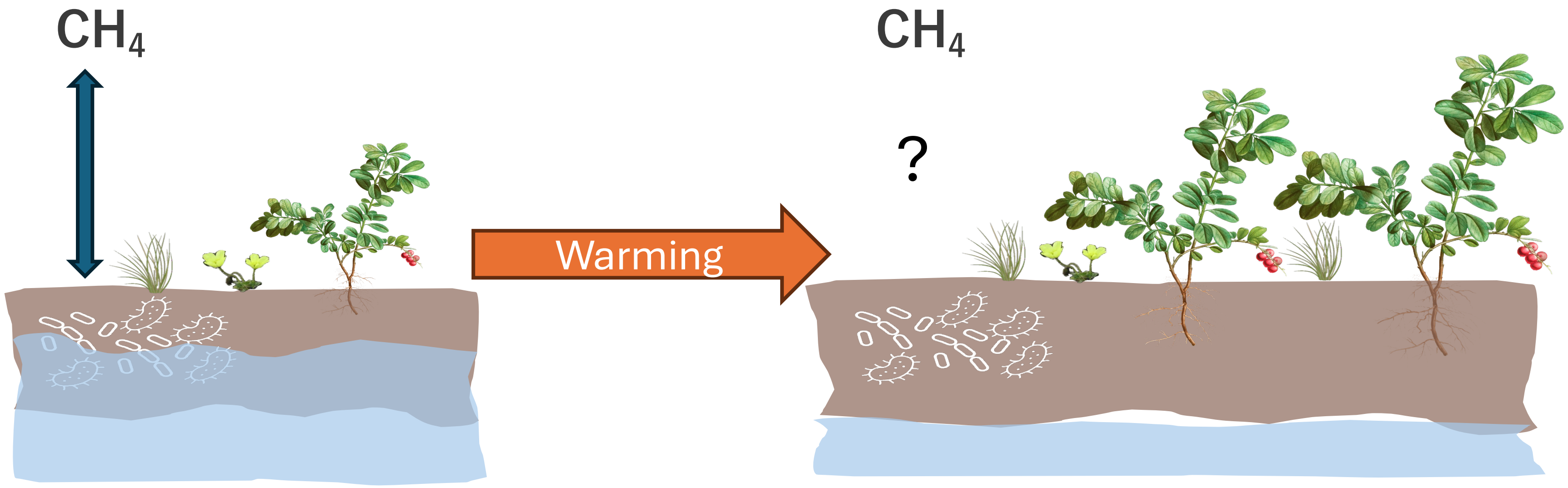
Remember Ellens Talk!

30% increase in growing season ecosystem respiration



Carbon Cycling CH4

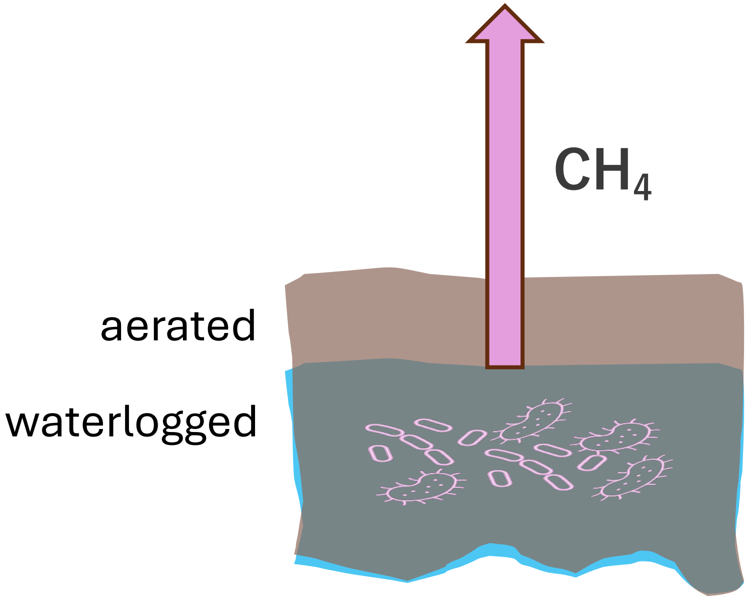
But how does the methane flux respond to warming?



Methane Dynamics

Methanogenesis

(Production of CH_4)

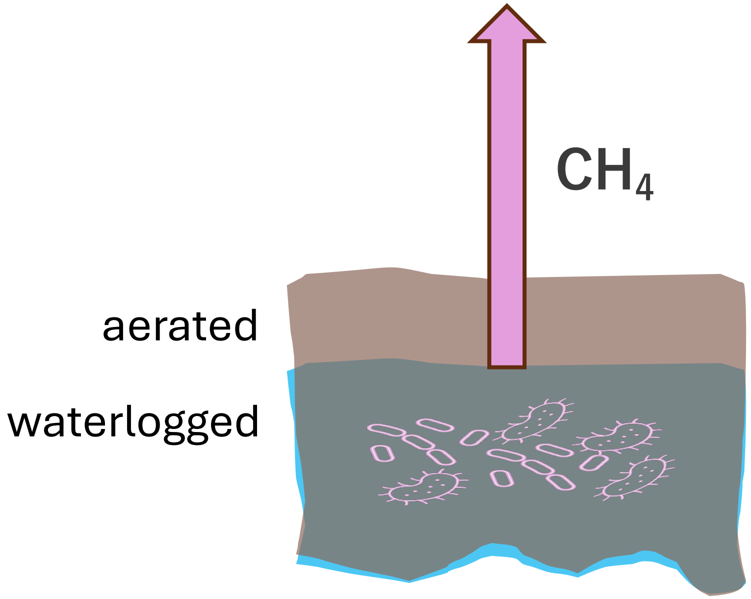


Methanogenic archea

anoxic conditions

Methane Dynamics

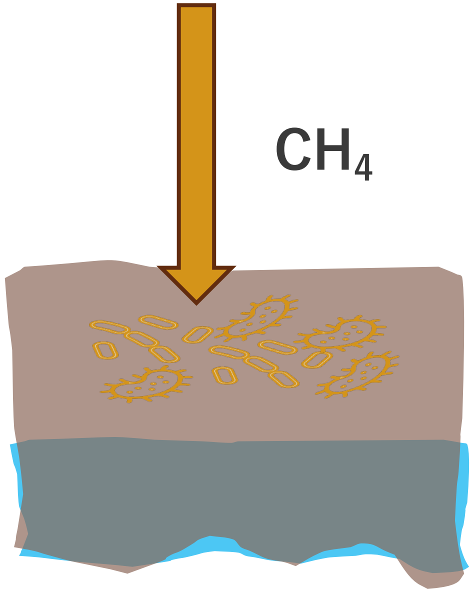
Methanogenesis
(Production of CH_4)



Methanogenic archea

anoxic conditions

Methane oxidation
(Consumption of CH_4)

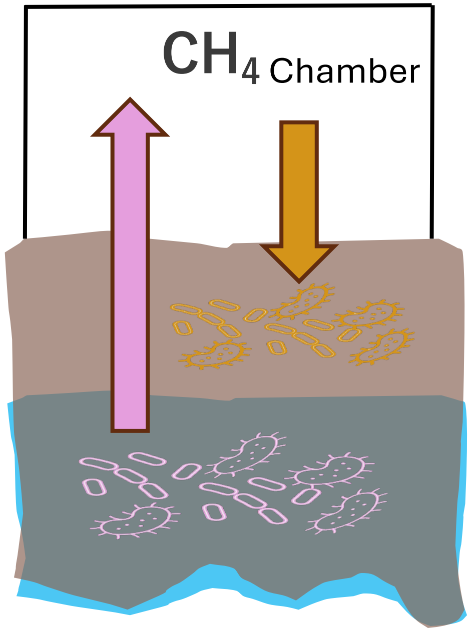


Methanotrophic bacteria

oxic conditions

Methane Flux

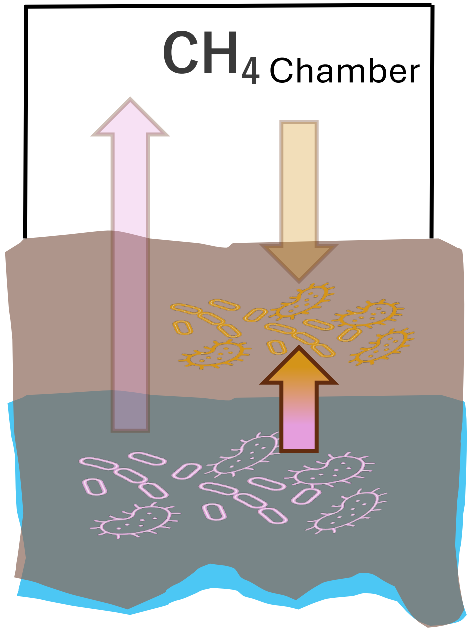
What we measure



Net flux = Production + Consumption

Methane Flux

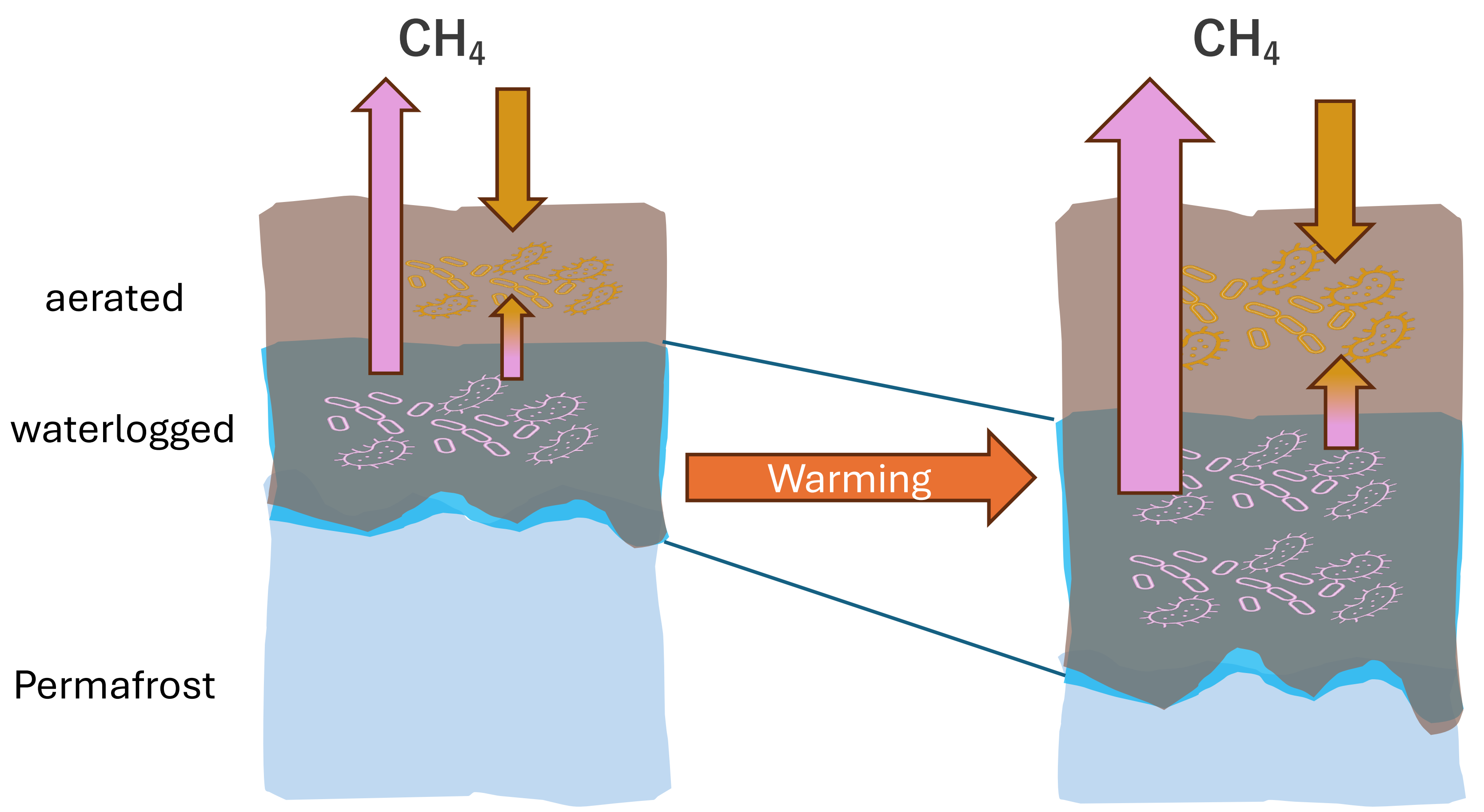
What we do not measure



Production + Consumption within the soil column

Methane Emissons

Increasing methane **emissions** with warming permafrost



Methane Emissons

Letter | Published: 01 December 2008

Large tundra methane burst during onset of freezing

Mikhail Mastepanov, Charlotte Sigsgaard, Edward J. Dlugokencky, Sander Houweling, Lena Ström, Mikkel P. Tamstorf & Torben R. Christensen

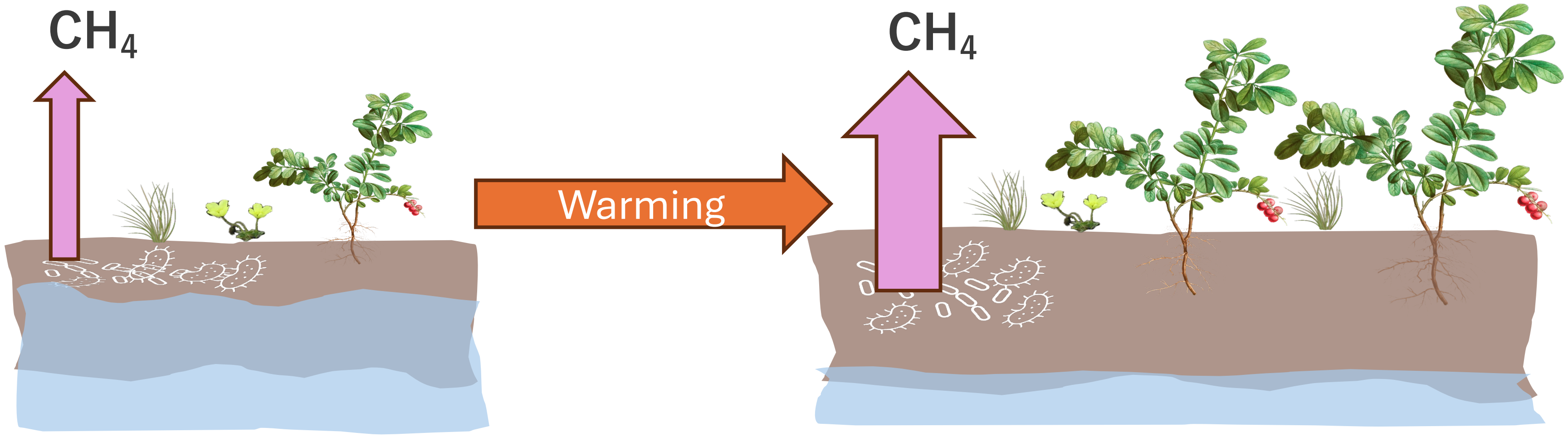
Nature **456**, 628–630 (2008) | Cite this article

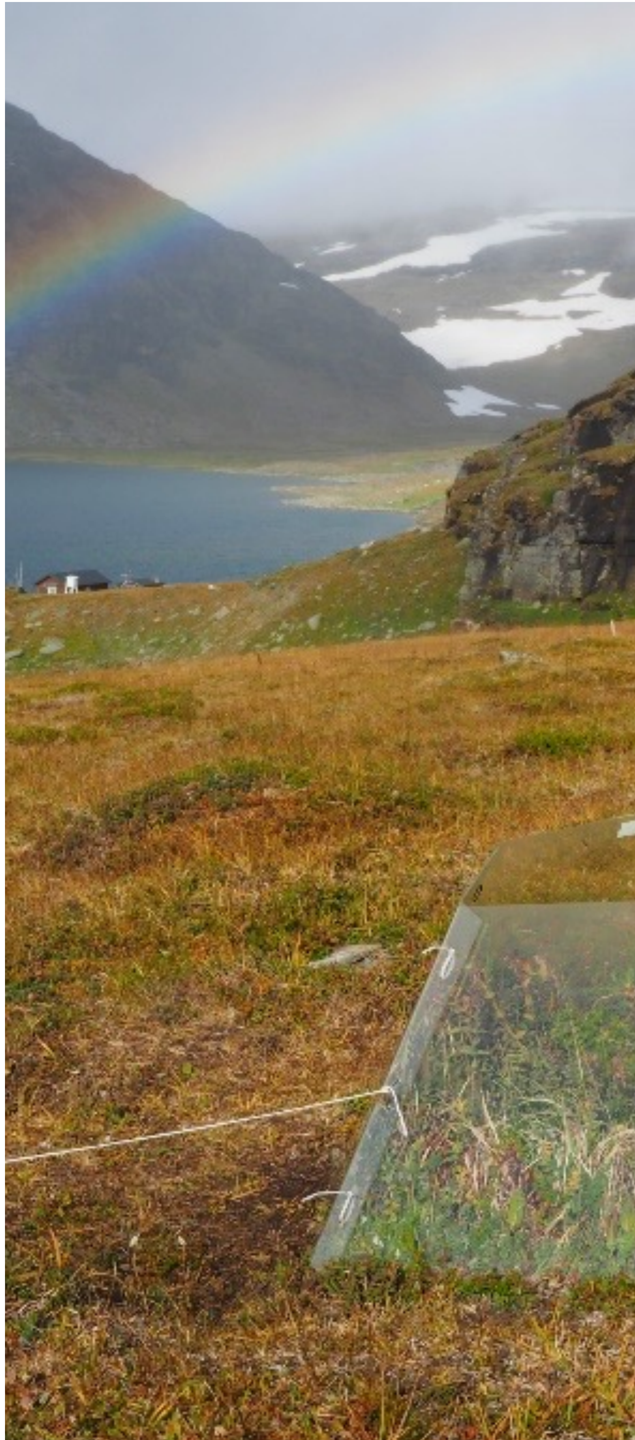
Article | Open access | Published: 27 October 2022

Seasonal increase of methane emissions linked to warming in Siberian tundra

Norman Rößger, Torsten Sachs, Christian Wille, Julia Boike & Lars Kutzbach

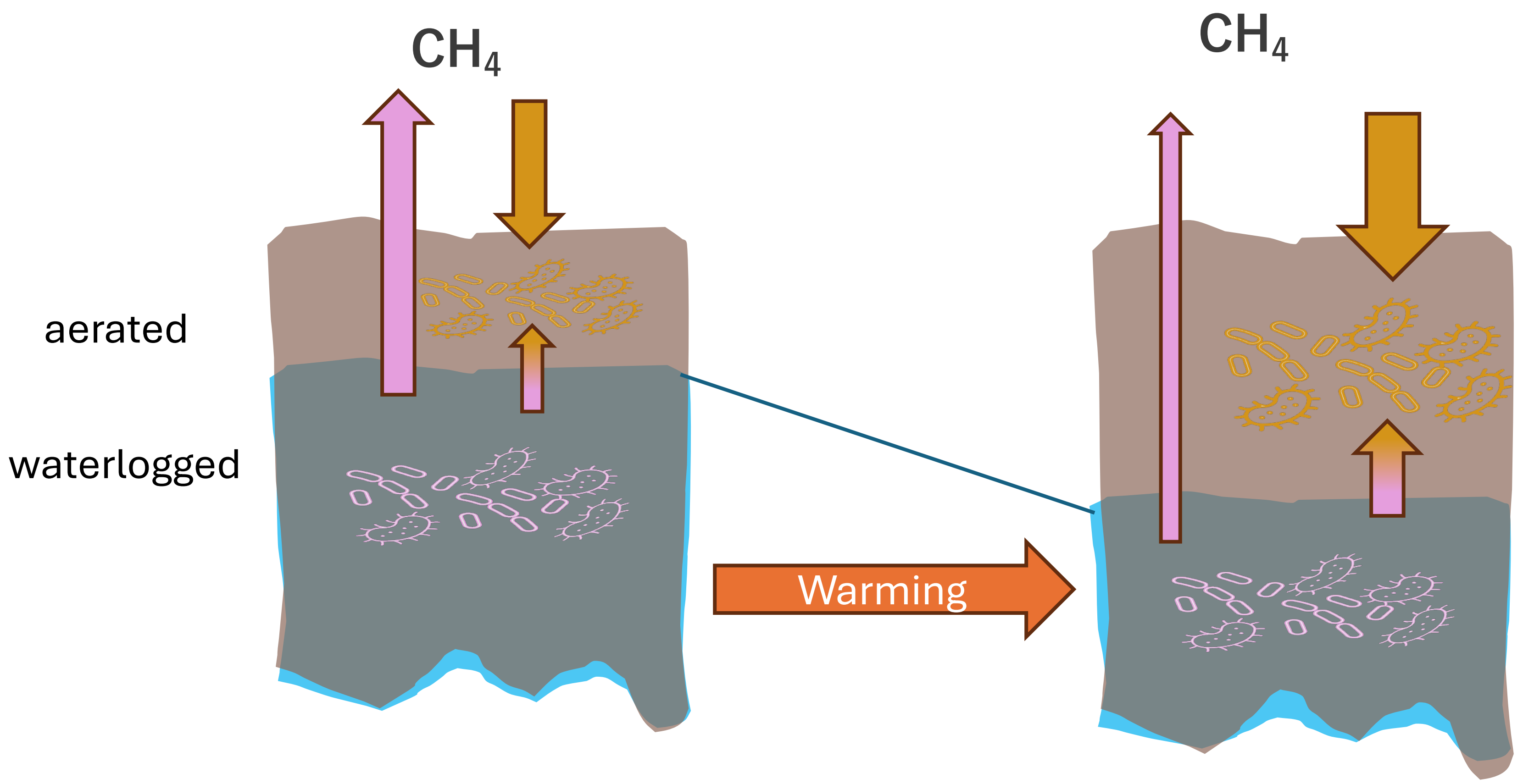
Nature Climate Change **12**, 1031–1036 (2022) | Cite this article





Methane Uptake

Increasing methane **uptake** with drier soil conditions



Methane Uptake

Article | Open access | Published: 31 August 2023

Arctic soil methane sink increases with drier conditions and higher ecosystem respiration

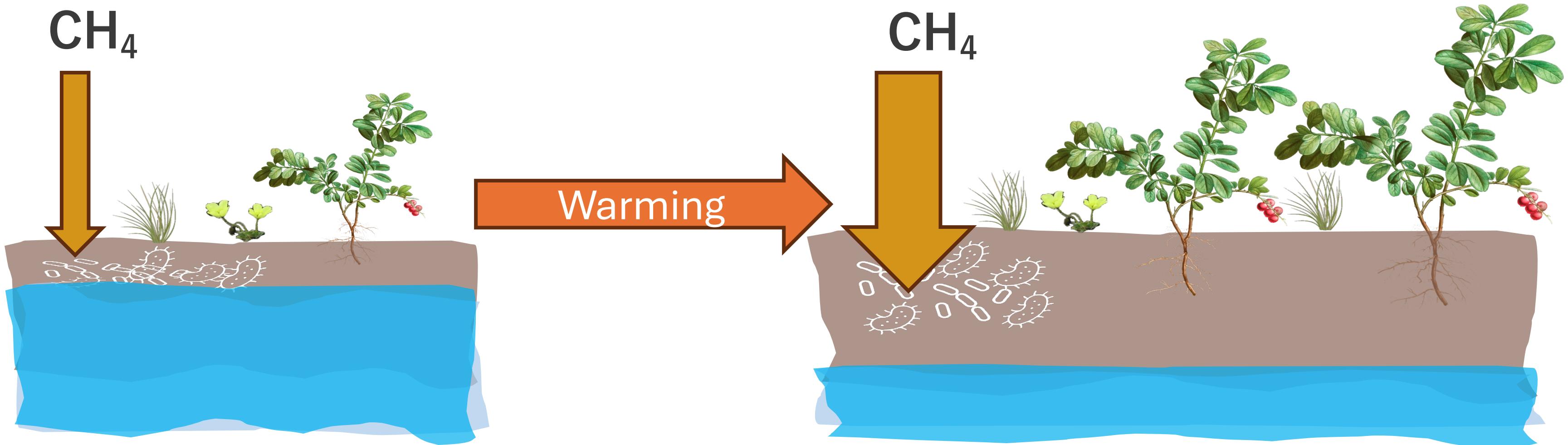
Carolina Voigt, Anna-Maria Virkkala, Gabriel Hould Gosselin, Kathryn A. Bennett, T. Andrew Black, Matteo Detto, Charles Chevrier-Dion, Georg Guggenberger, Wasi Hashmi, Lukas Kohl, Dan Kou, Charlotte Marquis, Philip Marsh, Maija E. Marushchak, Zoran Nesic, Hannu Nykänen, Taija Saarela, Leopold Sauheitl, Branden Walker, Niels Weiss, Evan J. Wilcox & Oliver Sonnentag

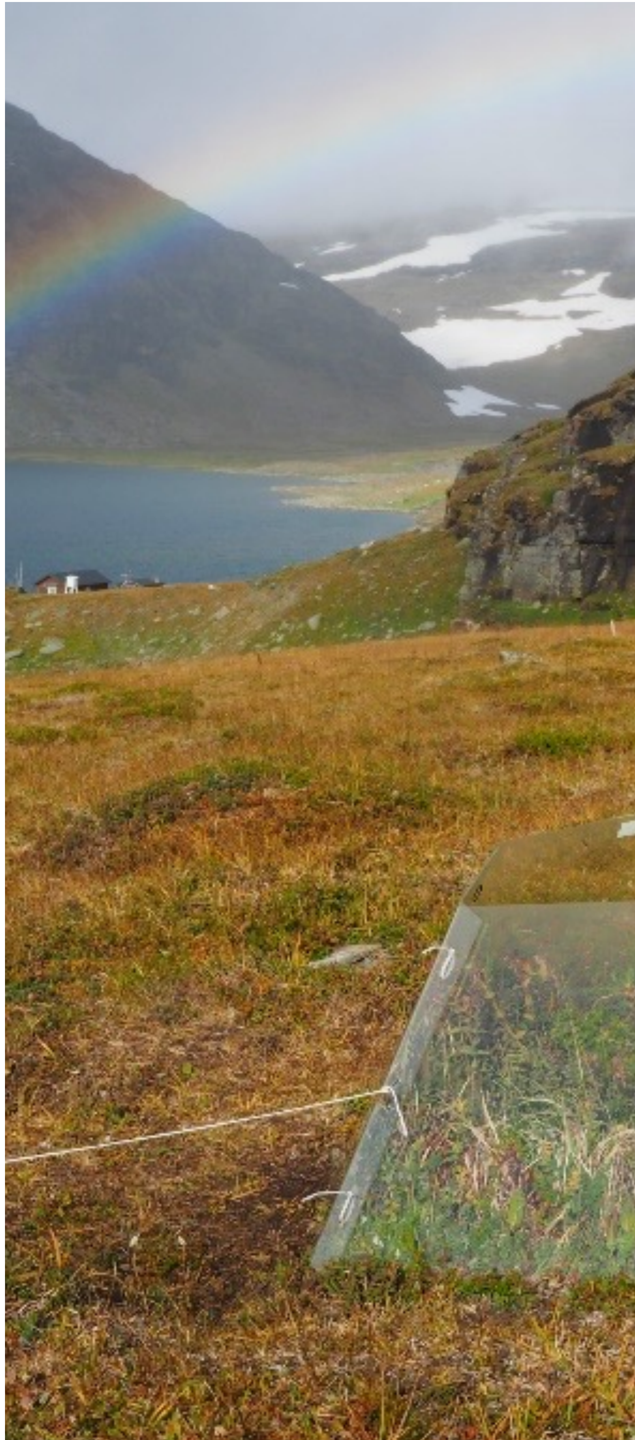
Nature Climate Change **13**, 1095–1104 (2023) | Cite this article

RESEARCH ARTICLE | Open Access

Reduced methane emissions in former permafrost soils driven by vegetation and microbial changes following drainage

Christoph Keuschnig, Catherine Larose, Mario Rudner, Argus Pesqueda, Stéphane Doleac, Bo Elberling, Robert G. Björk, Leif Klemedtsson, Mats P. Björkman



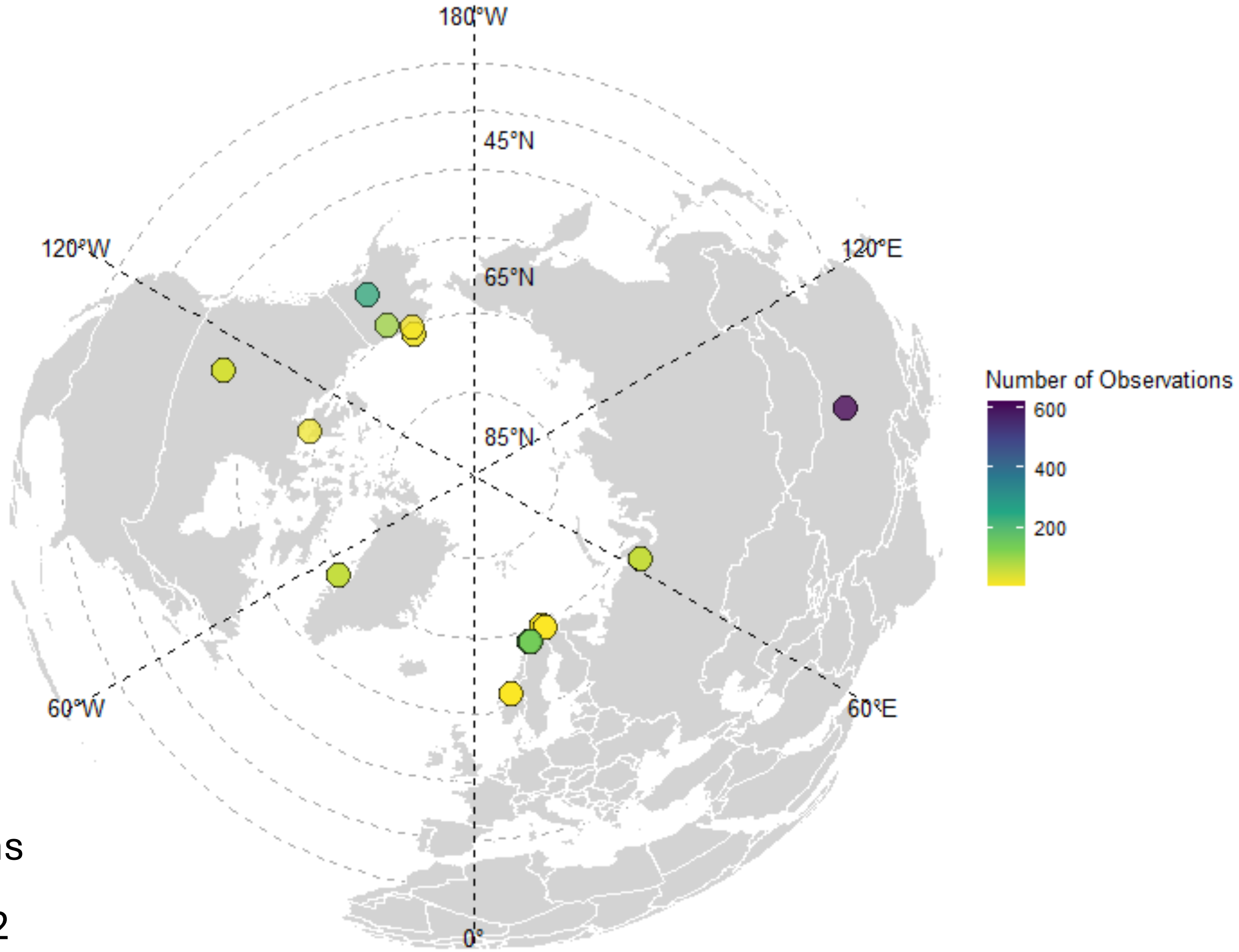


What we did

➔ Collection CH4-data from OTC experiments across the arctic

➔ Synthesize the response of methane to experimental warming

Meta Analysis



- 69 Datasets
- 39 Locations
- 2625 Observations
- from 1999 to 2022

Meta Analysis

$$SMD_{CH_4\,/site * year} = \frac{mean(CH_{4_{CTL}}) - mean(CH_{4_{OTC}})}{SD_{pooled}}$$

$$SMD_{CH_4\,/\,overall} = \text{mixed effect model}\,(\,SMD_{CH_4\,/site * year} + \text{moderators} + \varepsilon)$$

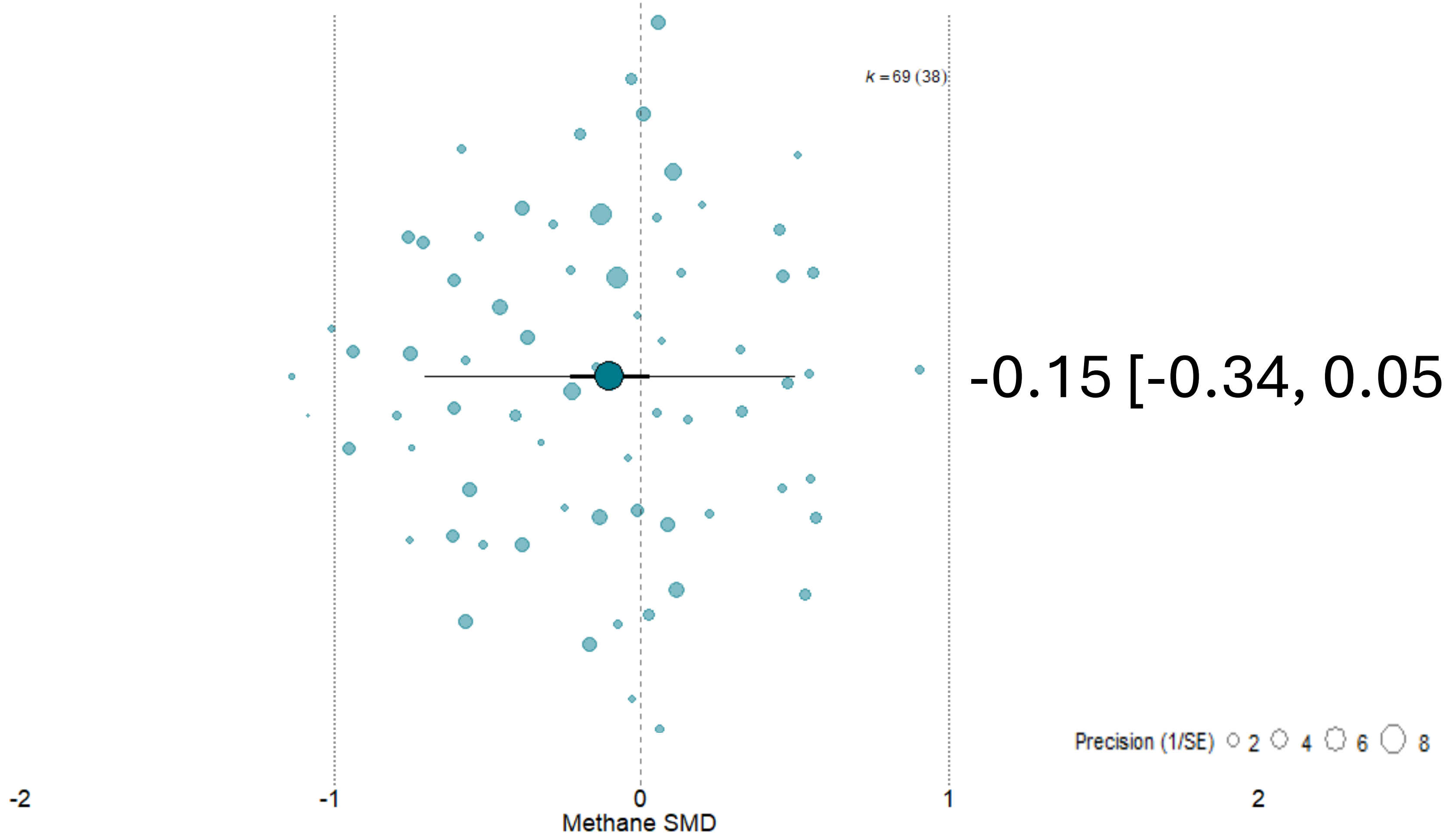
Positive SMD = **higher** net flux in OTC than CTL
Negative SMD = **lower** net flux in OTC than CTL

Small Effect	+- 0.2
Medium Effect	+- 0.5
Large Effect	+- 0.8

Summary

Decreasing methane net flux with warming

Increasing methane net flux with warming



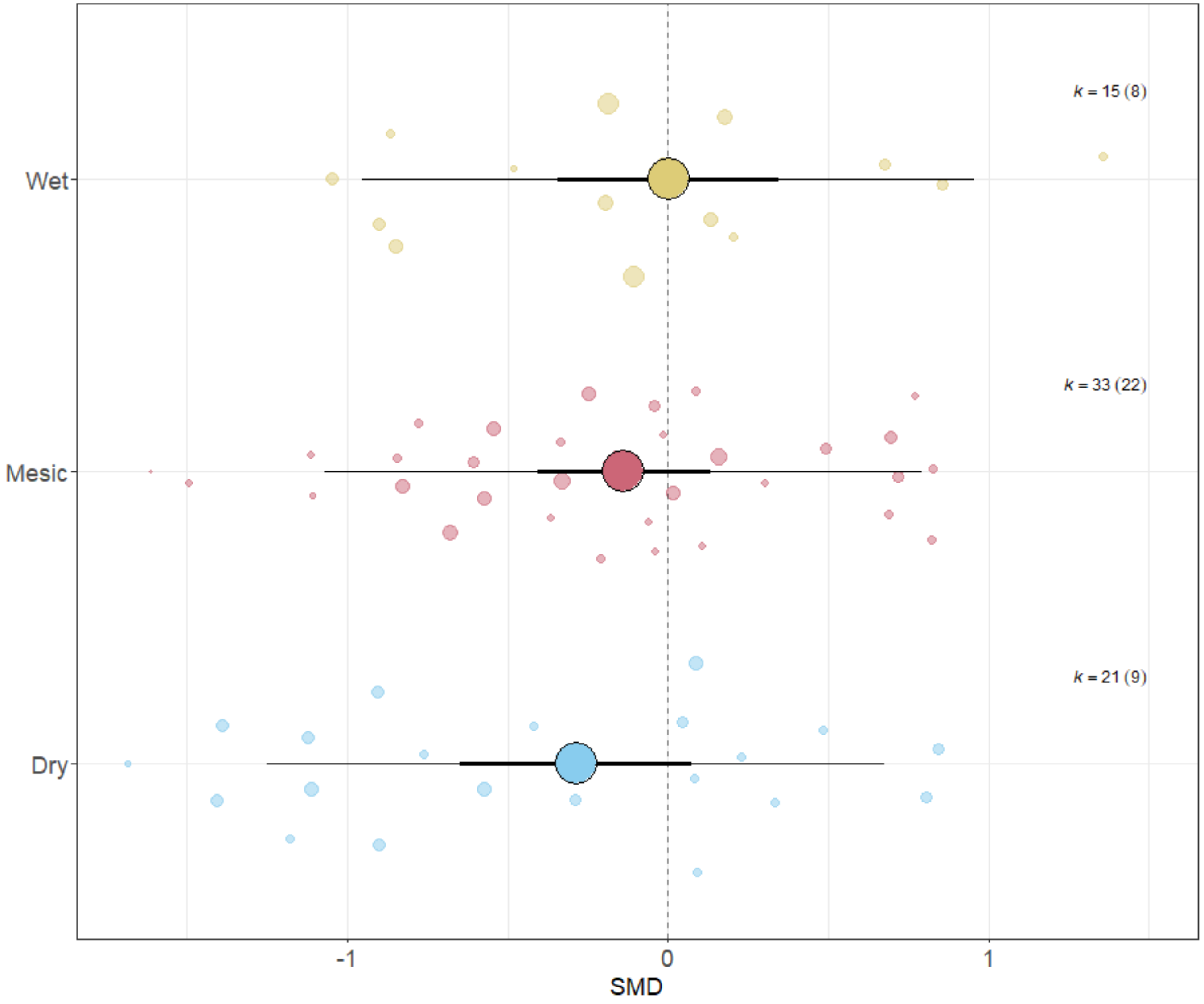
-0.15 [-0.34, 0.05]

Large negative effect

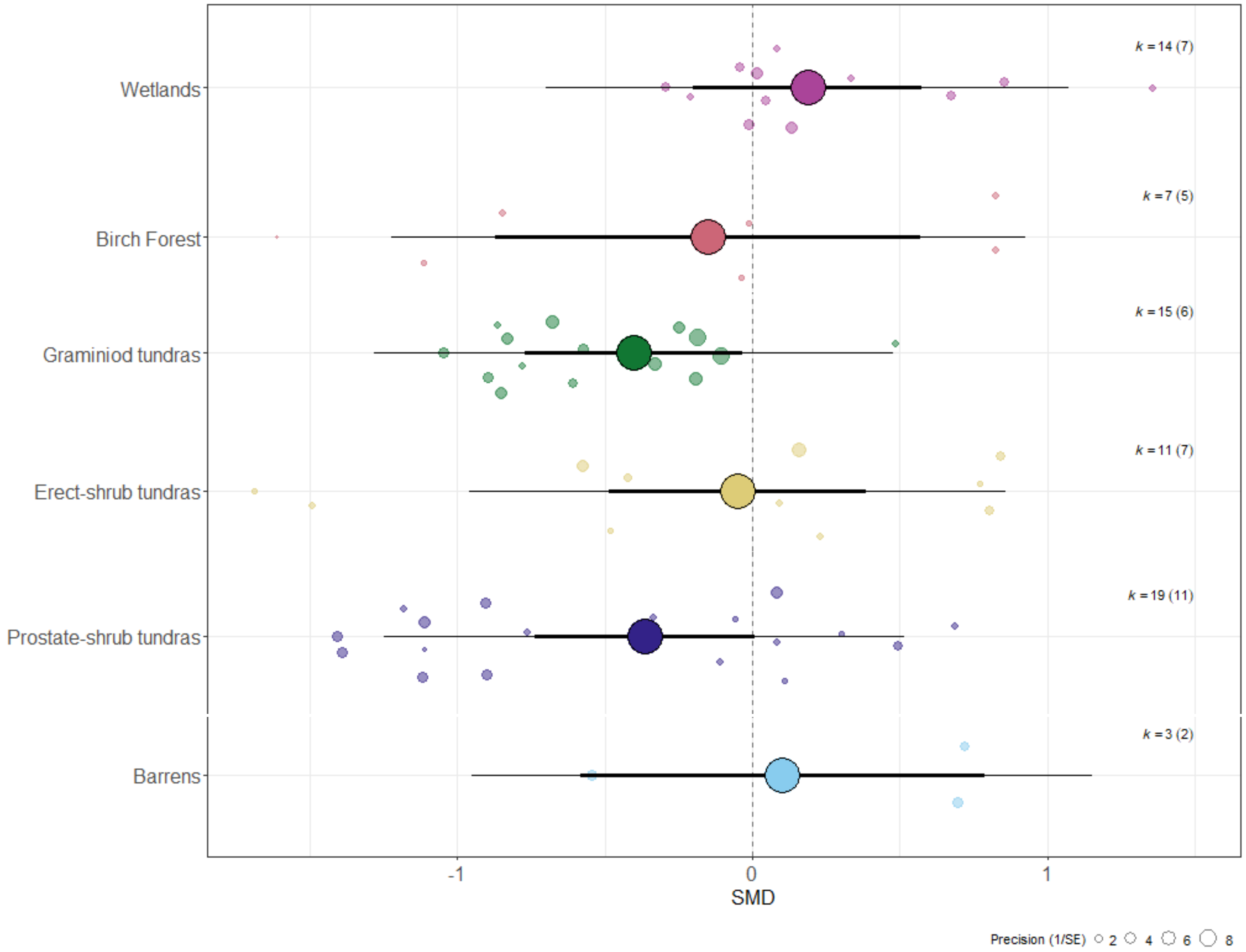
No effect

Large positive effect

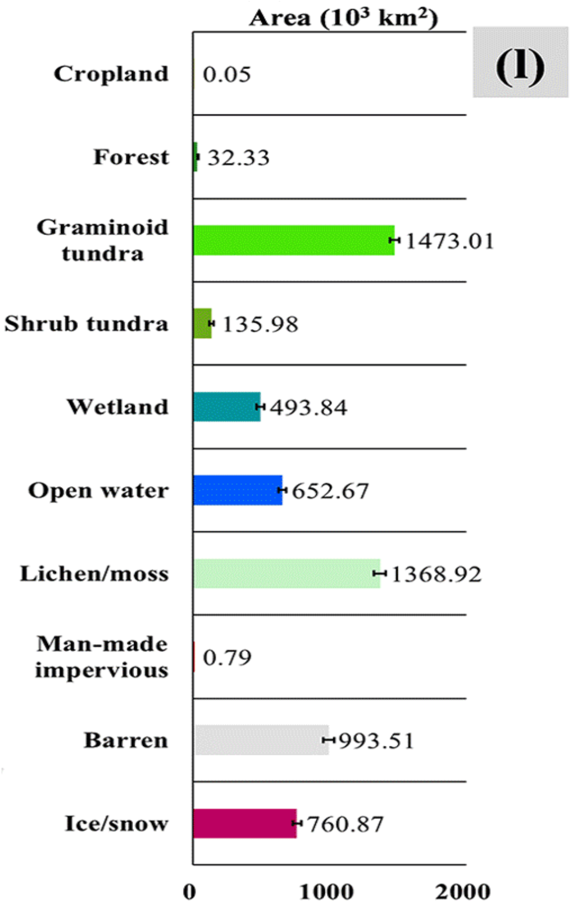
Soil Moisture Category



Vegetation Type

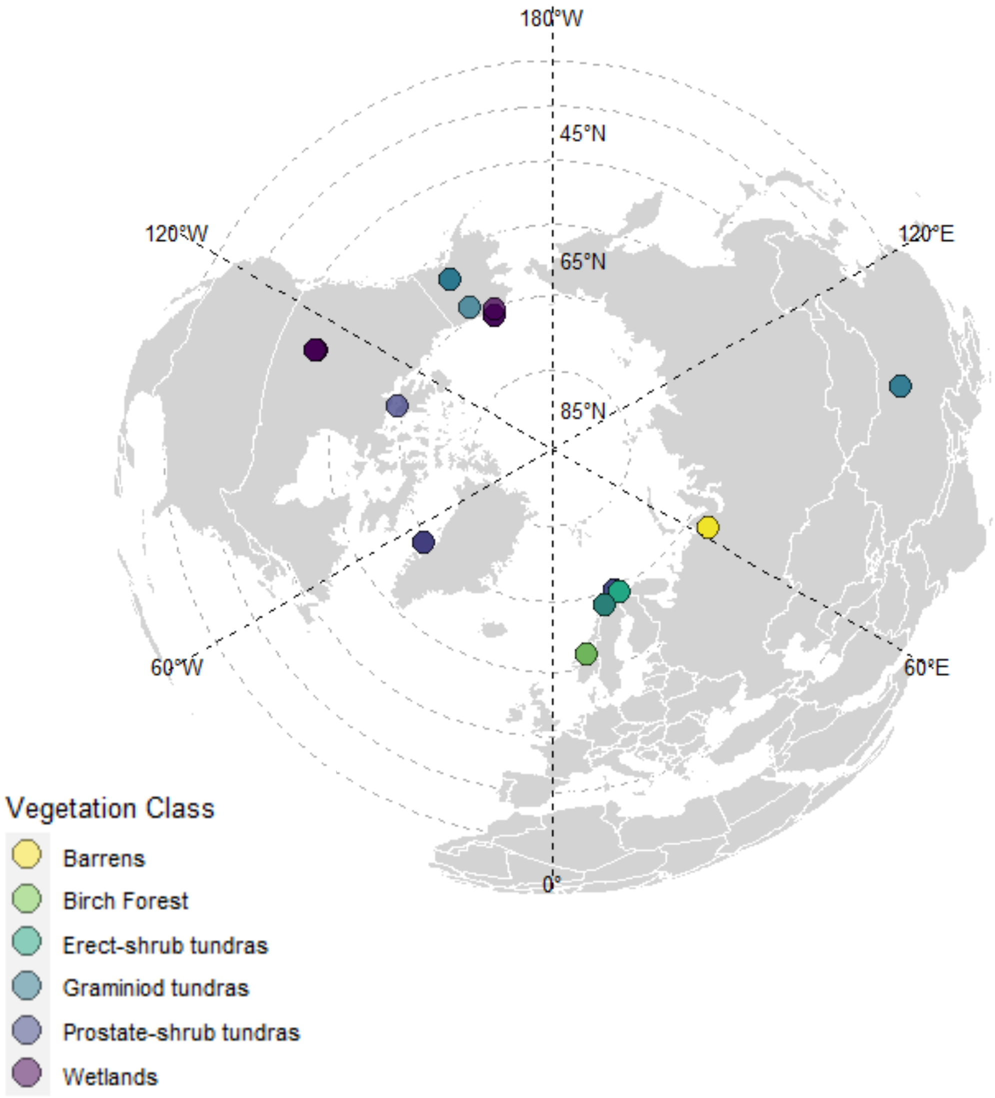


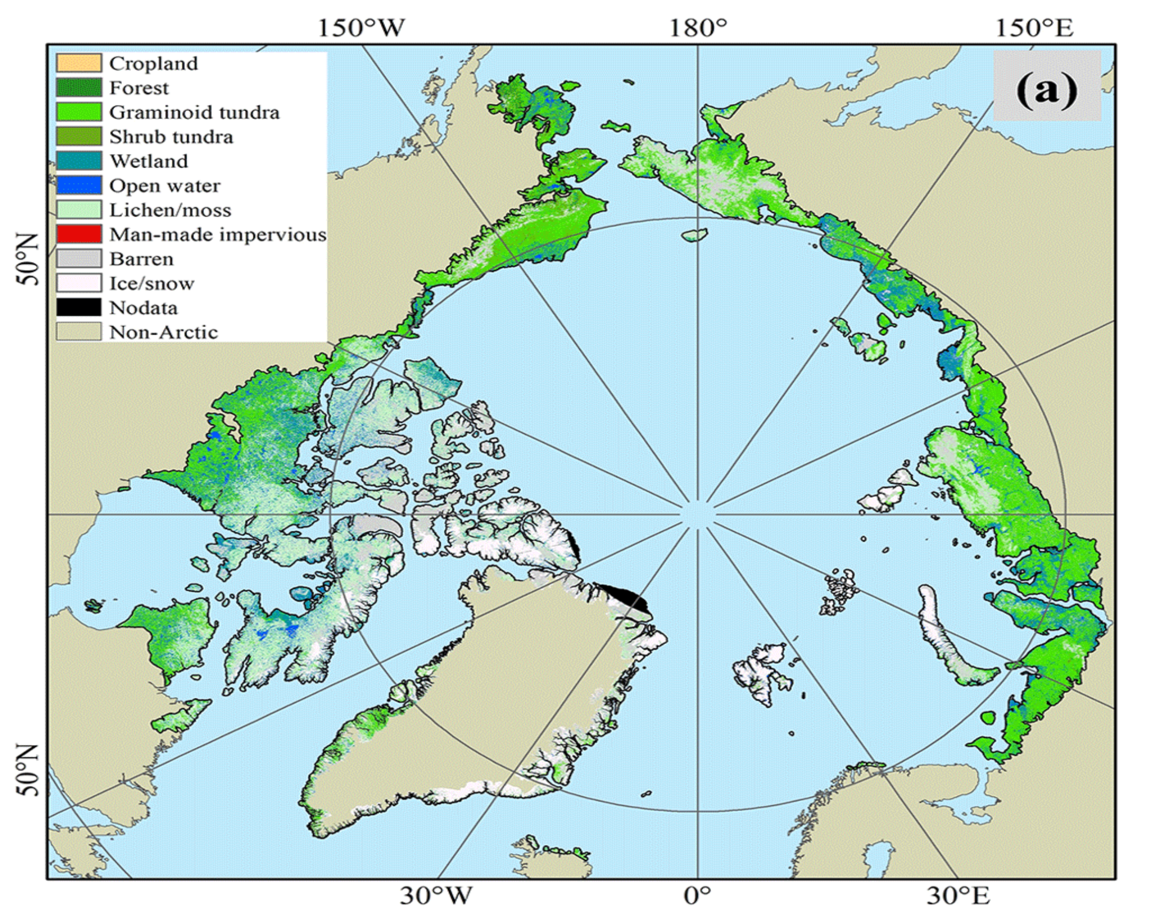
Vegetation Type



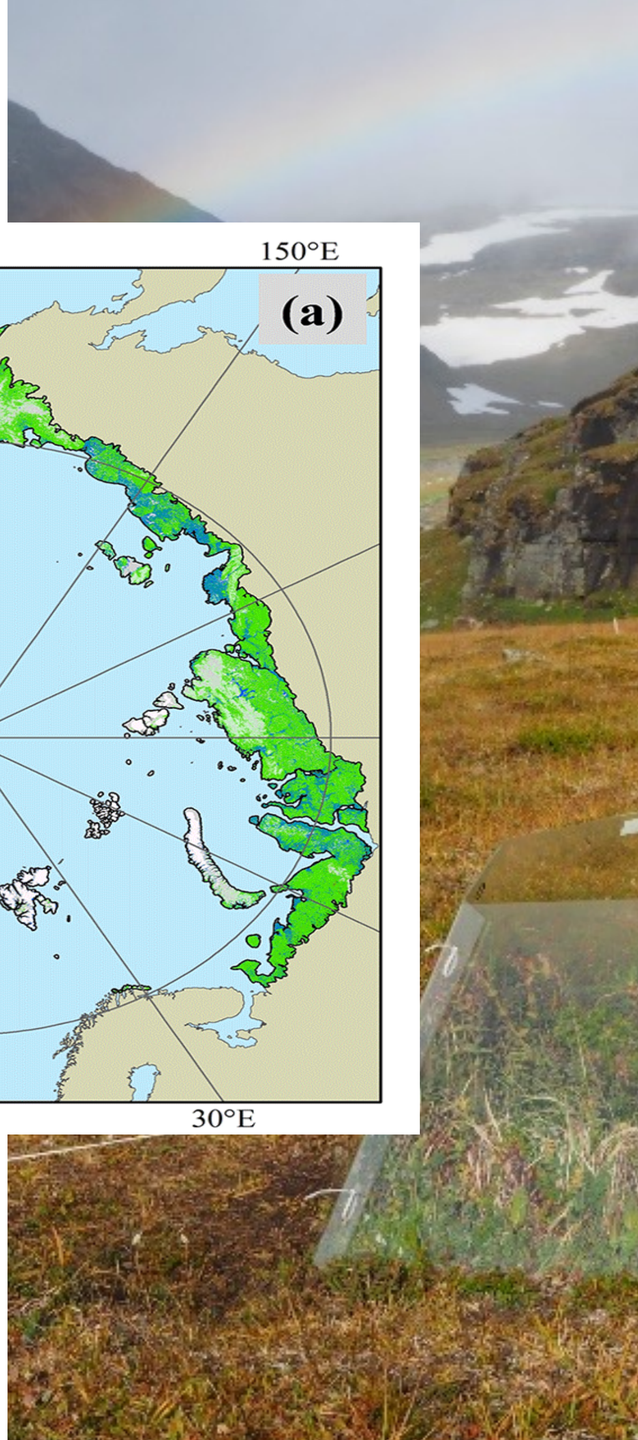
Liu et al. (2023)

Vegetation Type

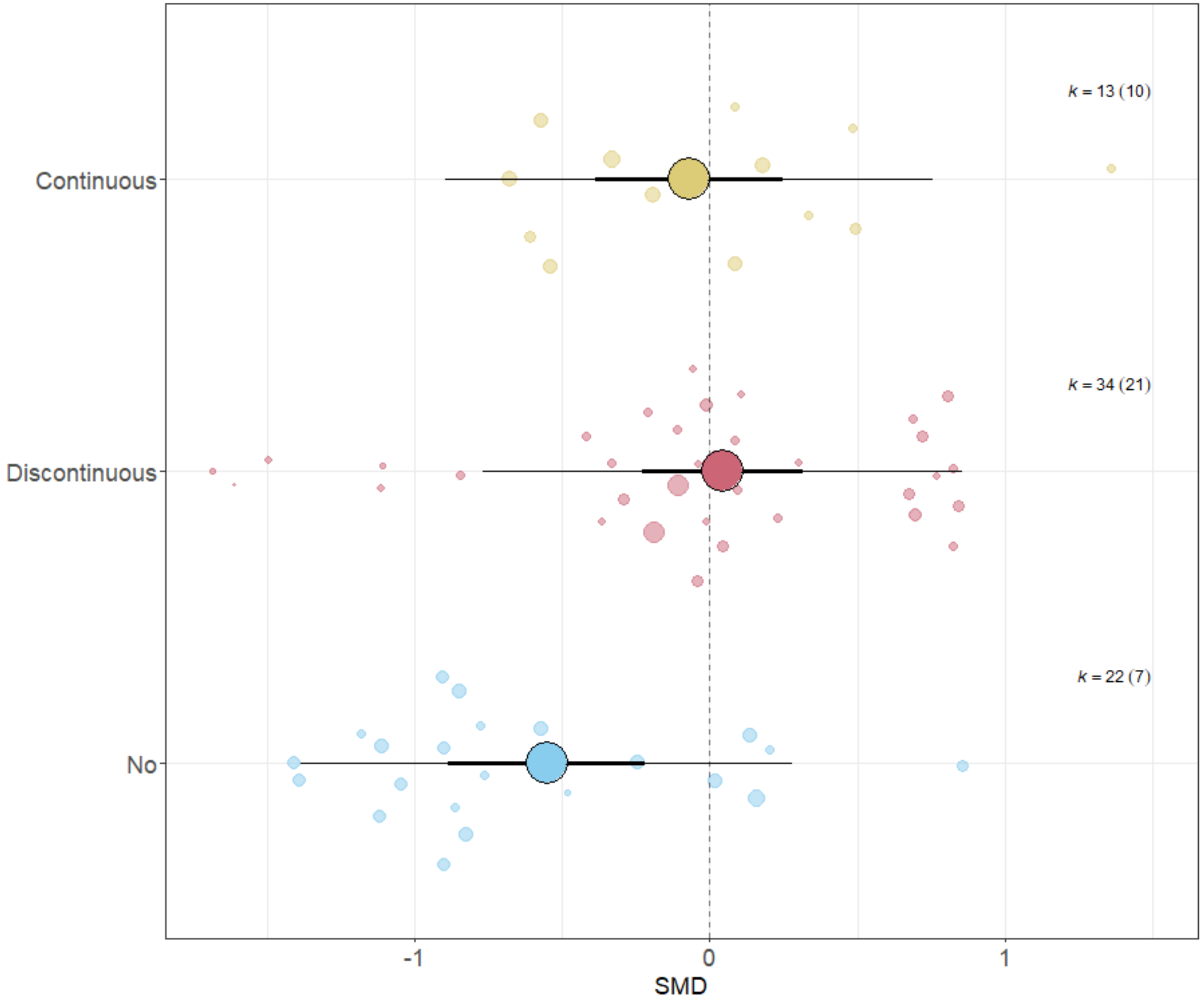




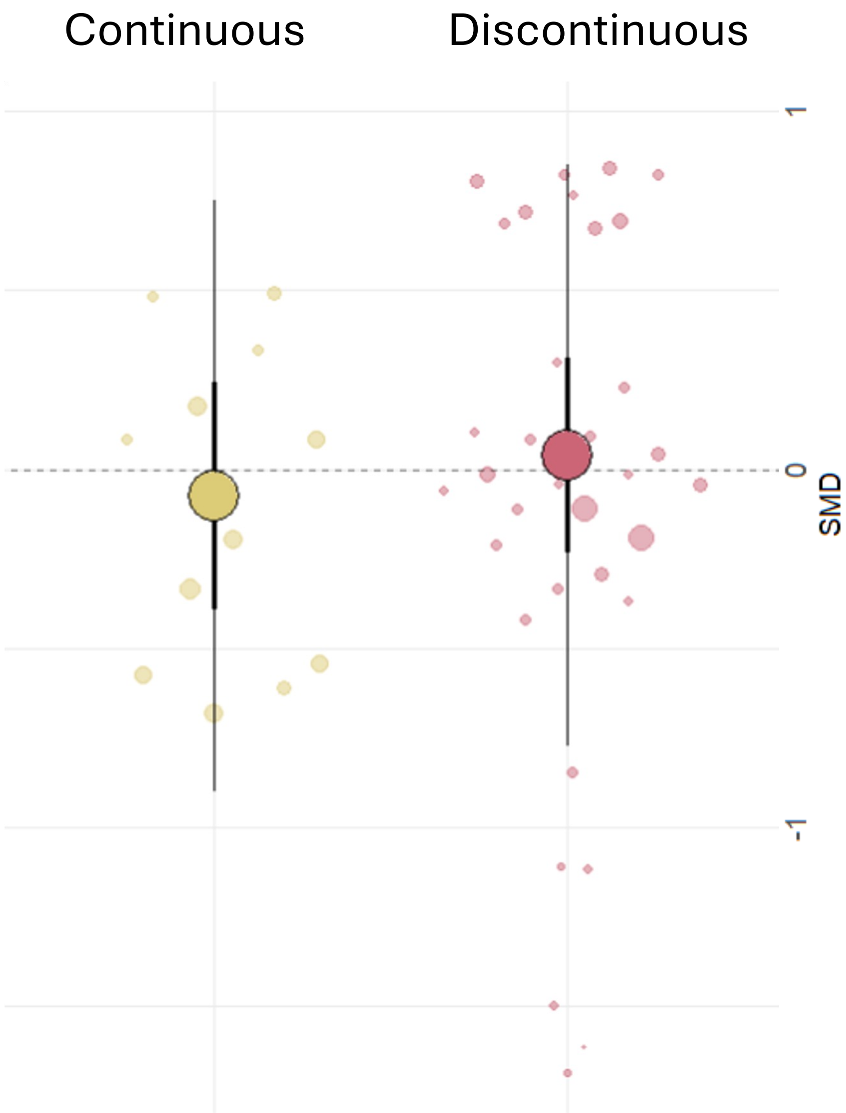
Liu et al. (2023)



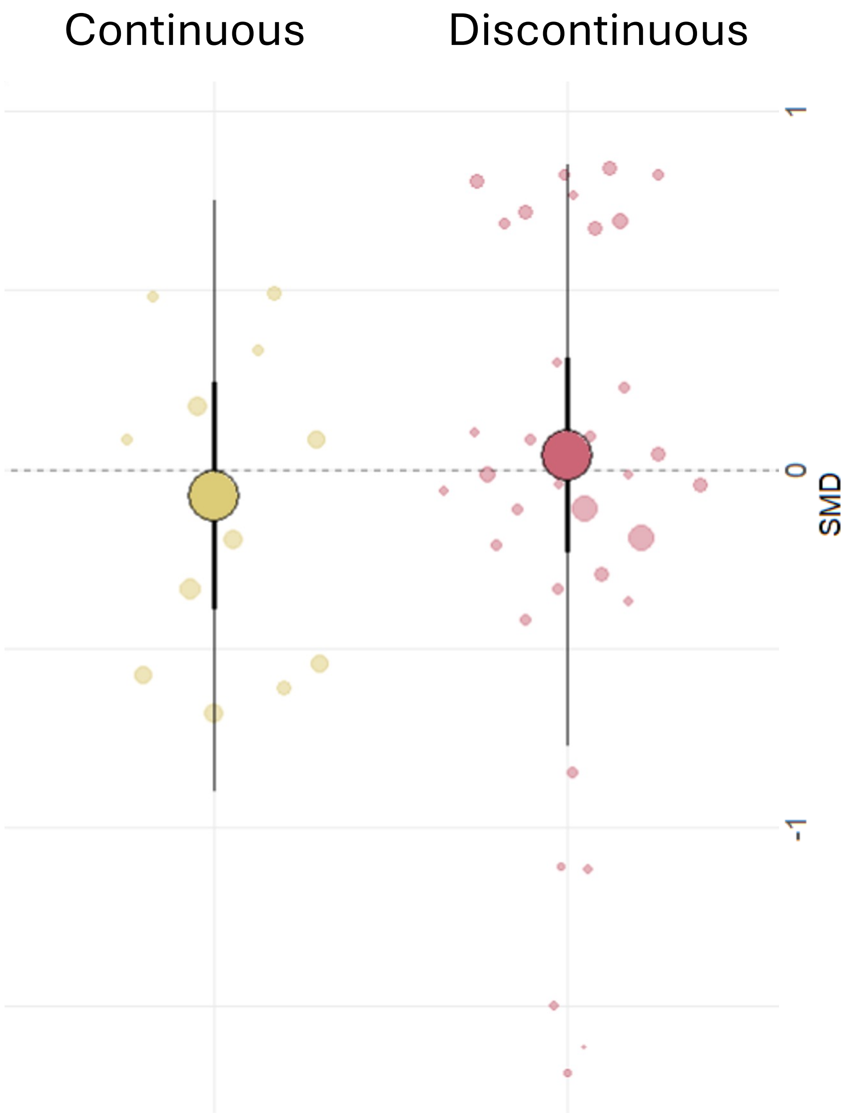
Permafrost

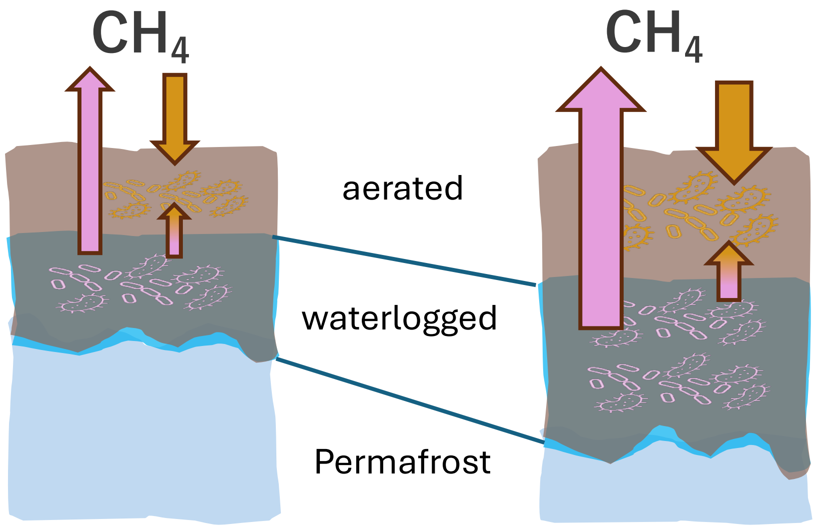


Methane in permafrost

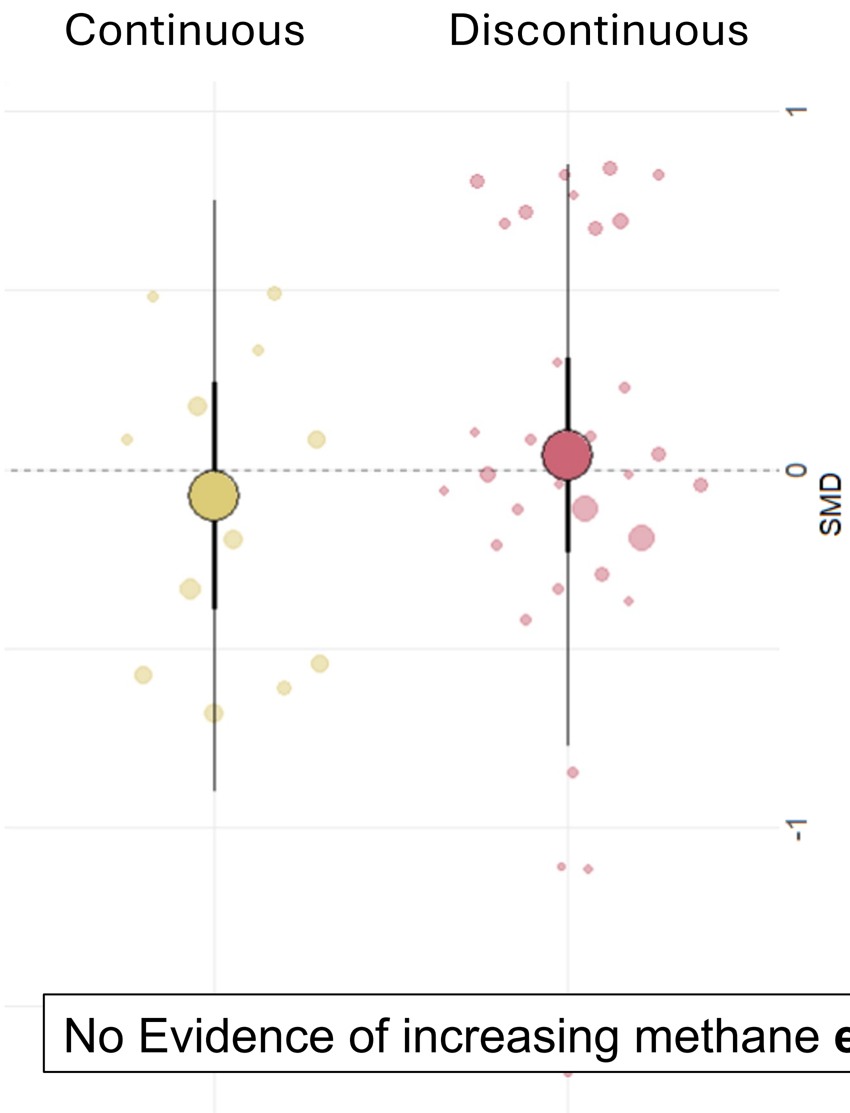


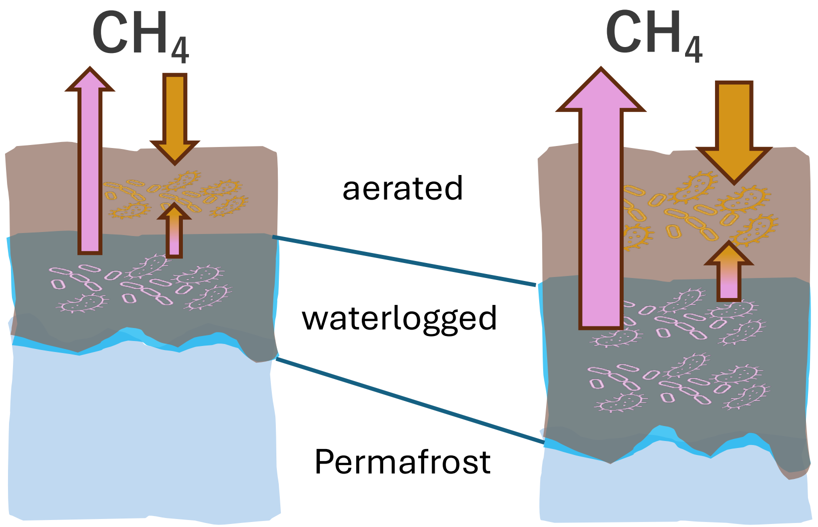
Methane in permafrost





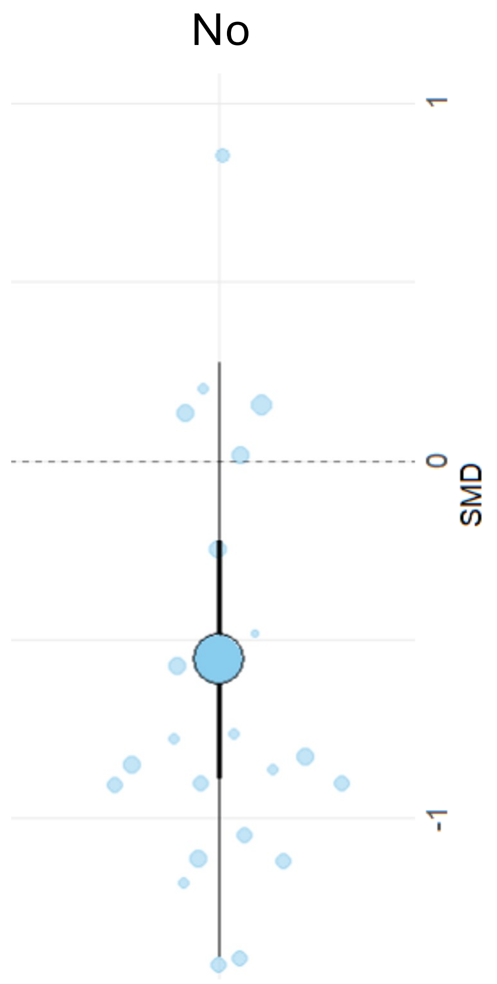
Methane in permafrost



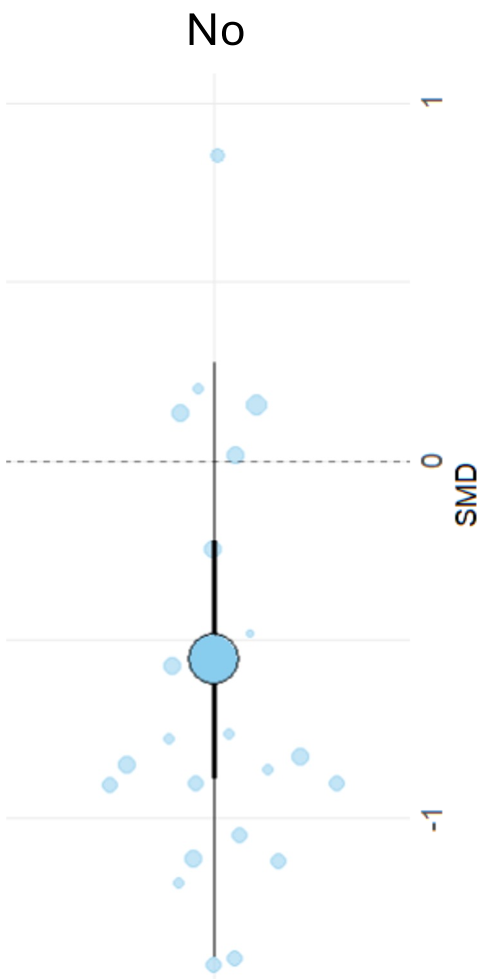


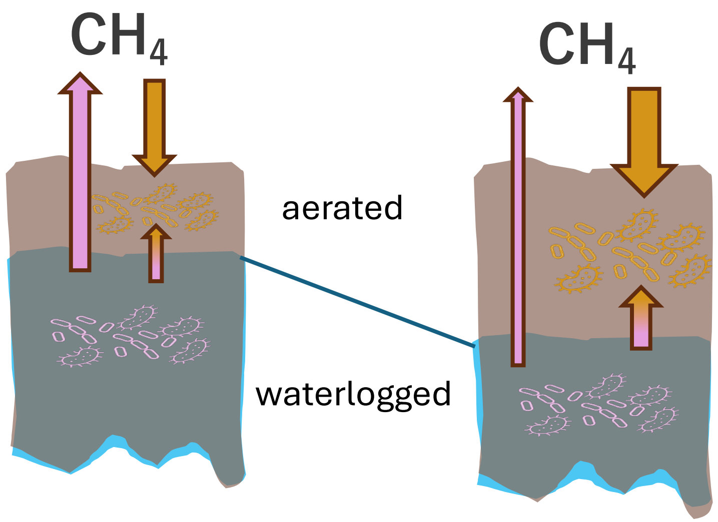
No Evidence of increasing methane **emissions** with warming in permafrost

No Permafrost

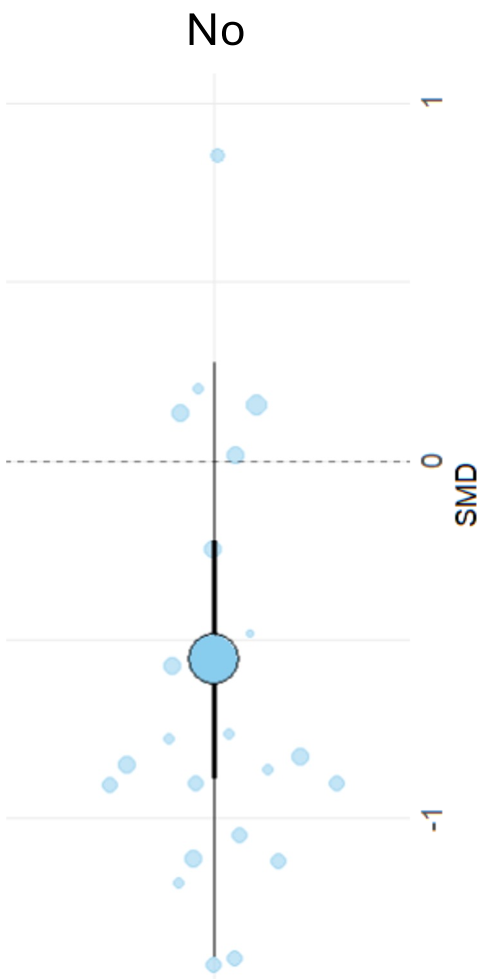


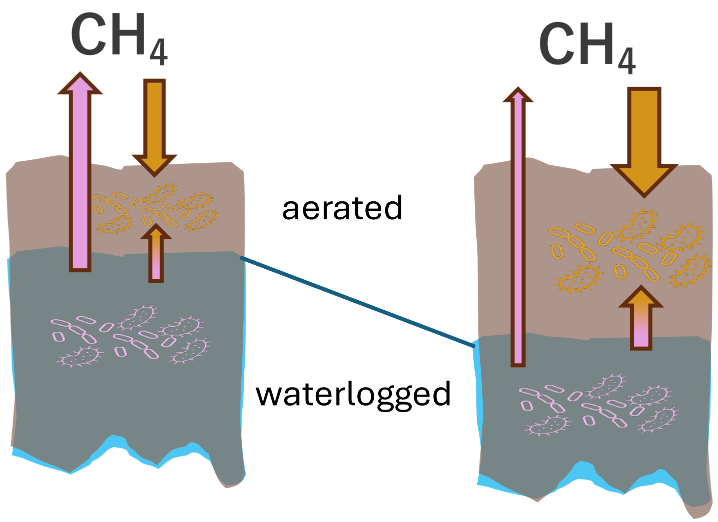
No Permafrost





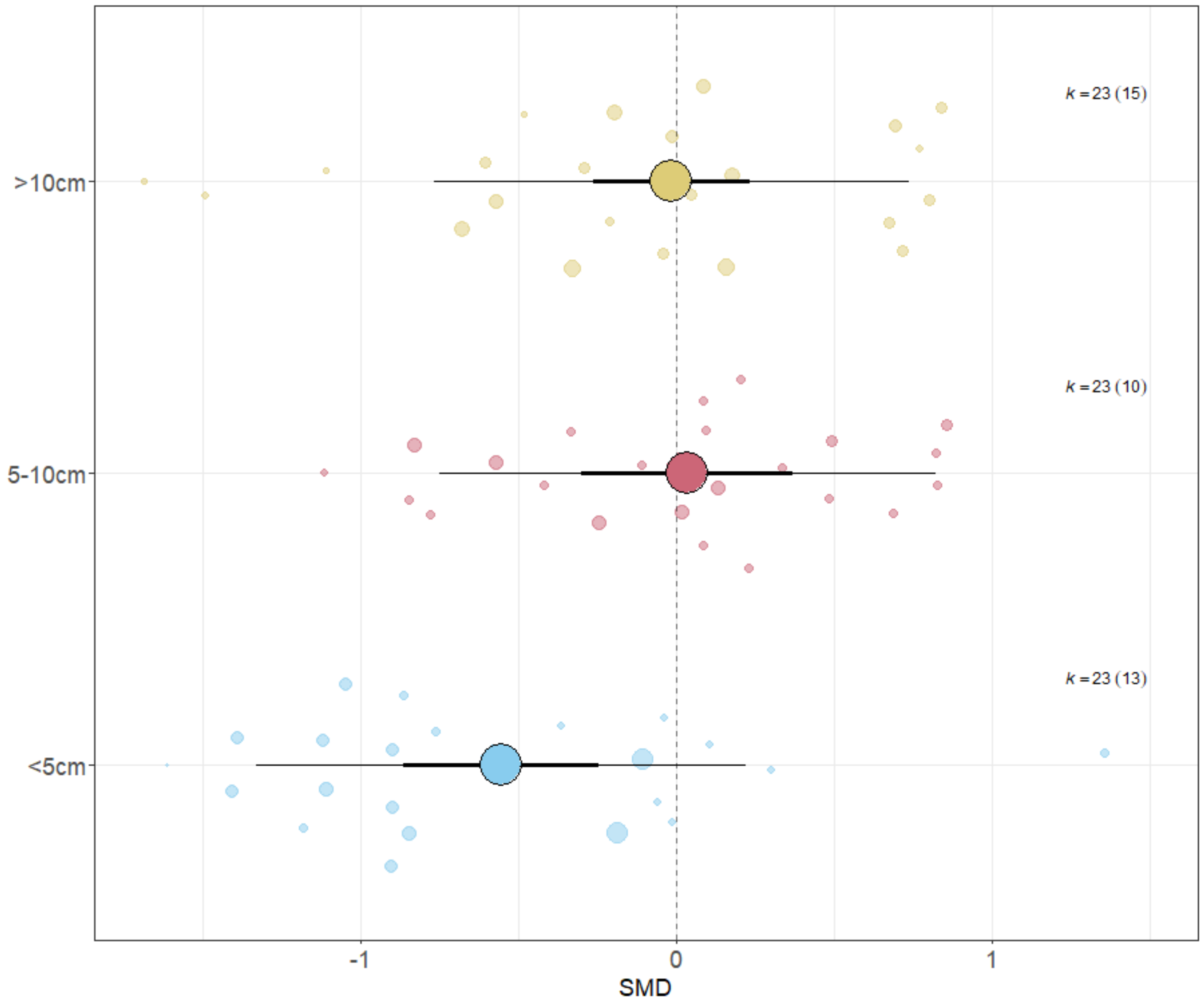
No Permafrost



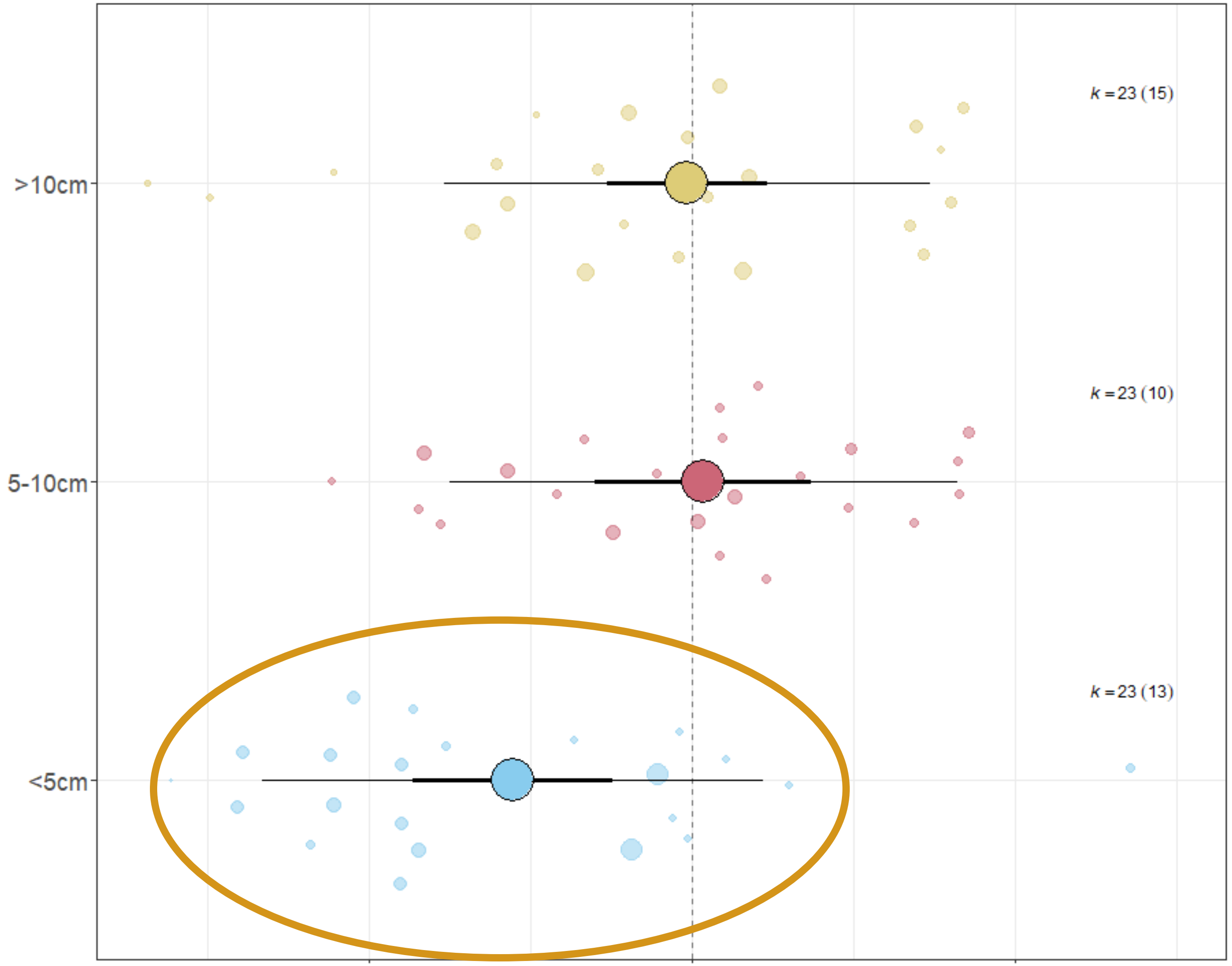


Decrease in **net methane flux** in **non-permafrost soils**

Organic Layer Depth

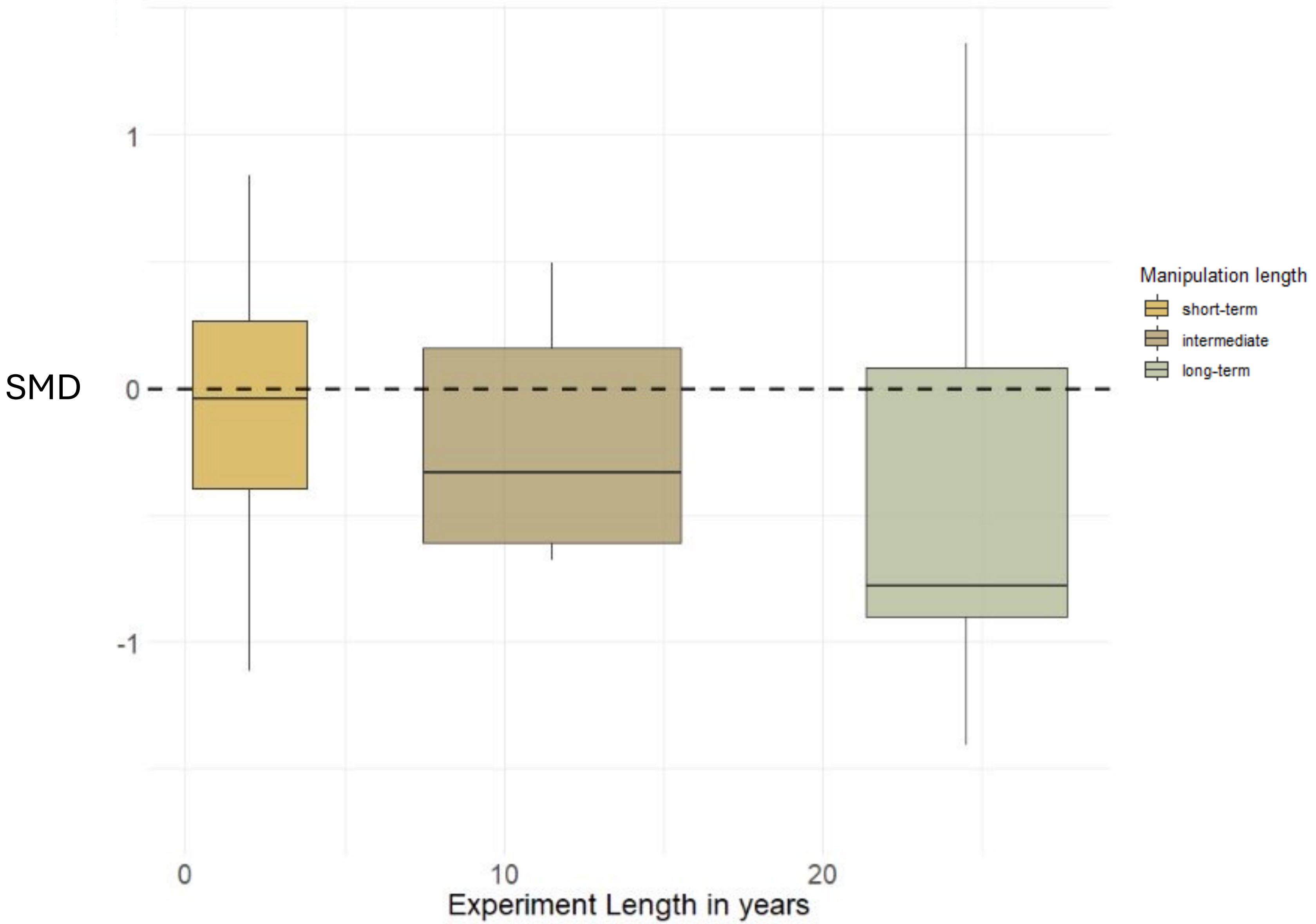


Organic Layer Depth

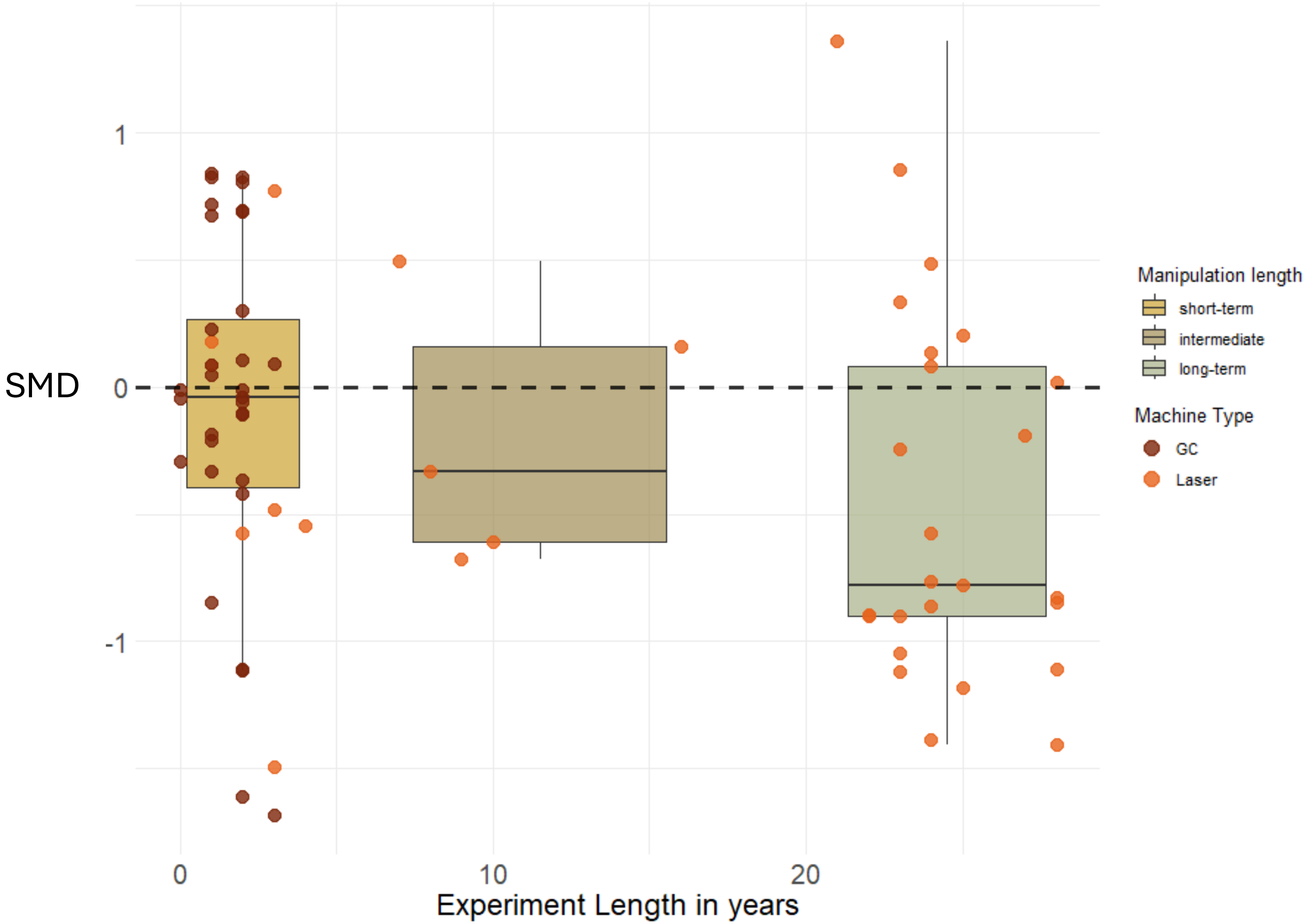


Decrease in **net methane flux** in **thin organic layers**

Experiment Duration



Experiment Duration



Take home message

Tendency for decrease in net methane flux in **graminoid** and **prostate-shrub tundra**

Decrease in net methane flux in soils with **thin organic layer**

Decrease in net methane flux in **non-permafrost soils**

→ Potentially **increased** methane **consumption**

Uncertainties: **Temporal trajectory** (measurement devices)

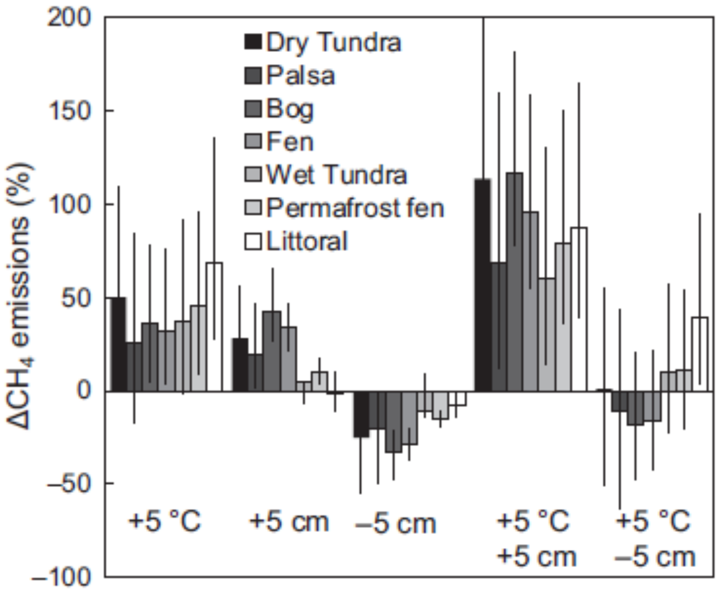
Spatial extent (sampling locations)

Thanks!

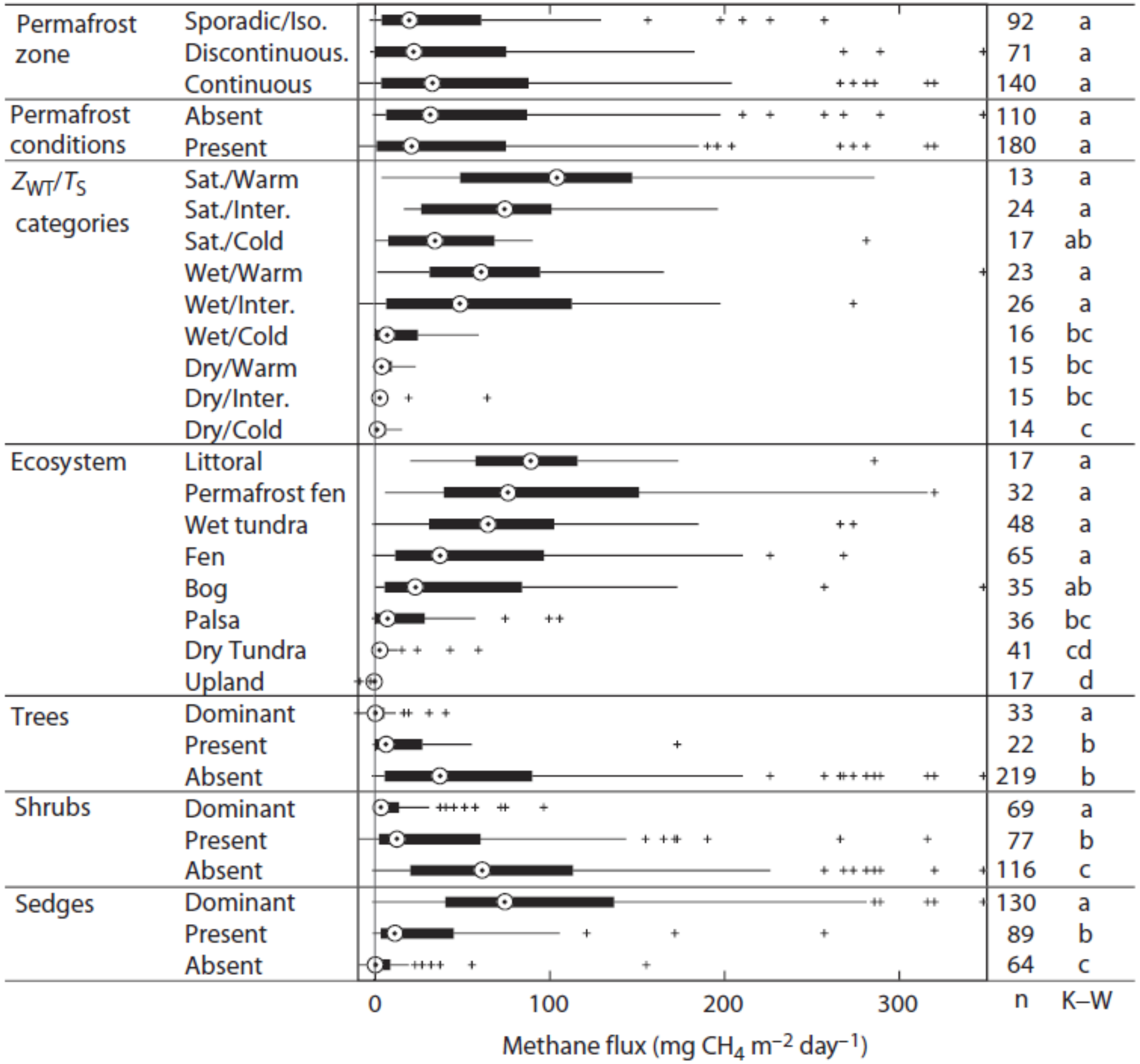
Sybryn Maes
Mats P. Björkman
Judith Sarneel
Ellen Dorrepaal
Sarah Schwieger
Niki Leblans

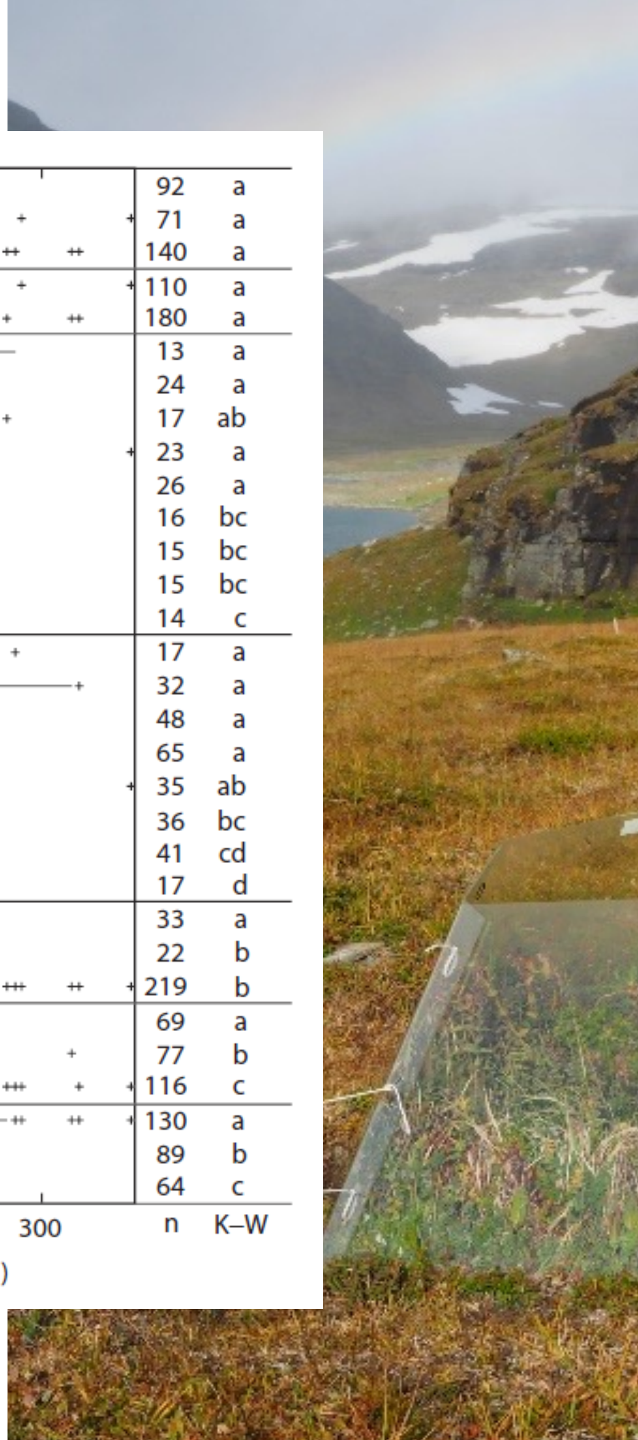
R. Aerts, I.H.J. Althuizen, C. Biasi, R.G.B. Björk, H. Böhner, M. Carbognani, G. Chiari, C.T. Christiansen, K.E. Clemmensen, E.J. Cooper, J.H.C. Cornelissen, B. Elberling, P. Faubert, N. Fetcher, T.G.W. Forte, J. Gaudard, K. Gavazov, Z.-H. Guan, J. Guðmundsson, R. Gya, S. Hallin, B.B. Hansen, S.V. Haugum, J.-S. He, C. Hicks Pries, M.J. Hovenden, M. Jalava, I.S. Jónsdóttir, J. Juhanson, J.Y. Jung, E. Kaarlejärvi, M.J. Kwon, R.E. Lamprecht, M. Le Moullec, H. Lee, M.E. Marushchak, A. Michelsen, T.M. Munir, E. Myrsky, C.S. Nielsen, M. Nyberg, J. Olofsson, H. Óskarsson, T.C. Parker, E.P. Pedersen, M. Petit Bon, A. Petraglia, K. Raundrup, N.M.R. Ravn, R. Rinnan, H. Rodenhizer, I. Ryde, N.M. Schmidt, E.A.G. Schuur, S. Sjogersten, S. Stark, M. Strack, J. Tang, A, Tolvanen, J.P. Töpper, M.K. Väisänen, V. Vandvik, R.S. van Logtestijn, C. Voigt, J. Walz, J.T. Weedon, Y. Yang, H. Ylänne
+ probably a lot of assistants

Results

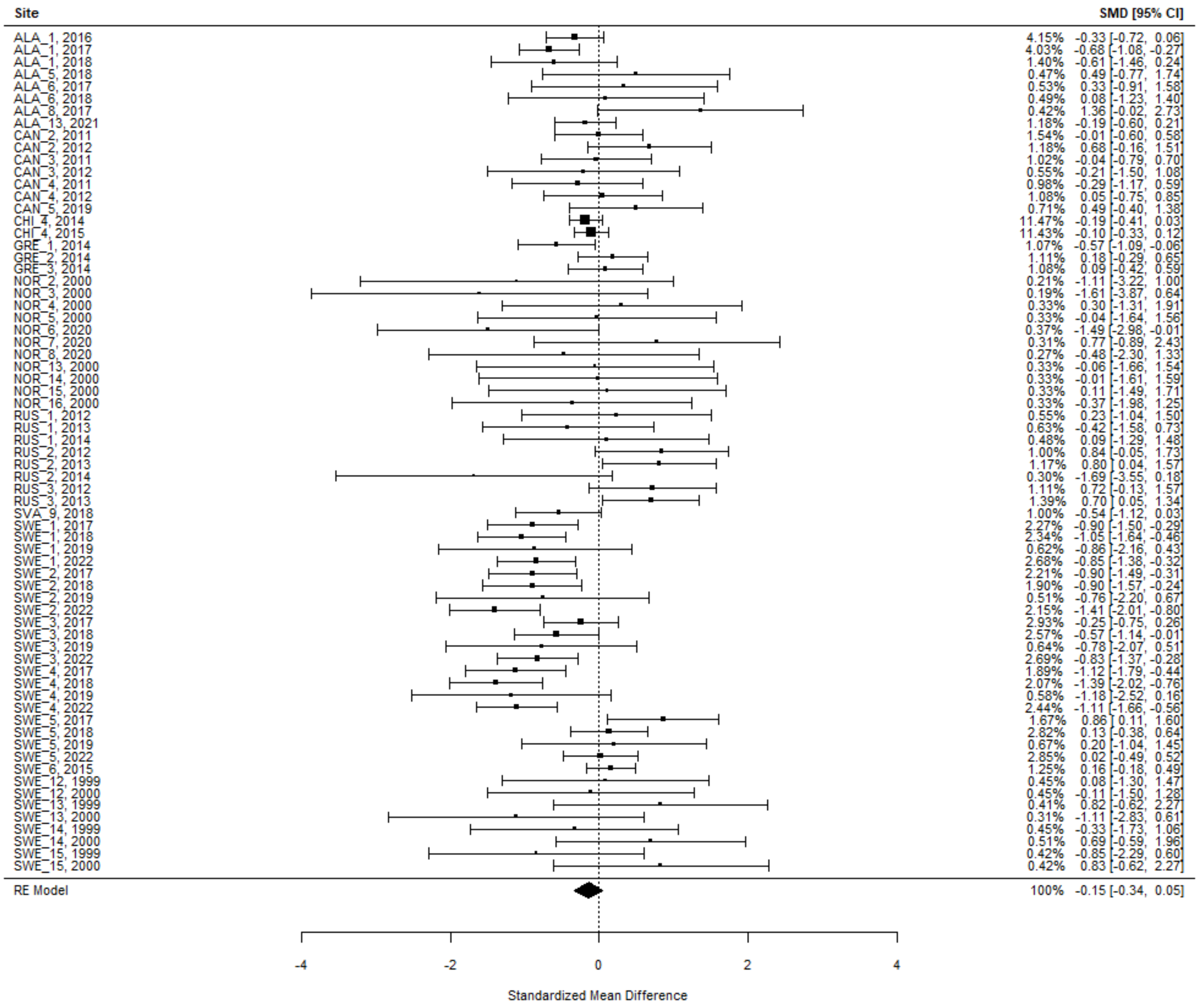


Olefeldt 2013



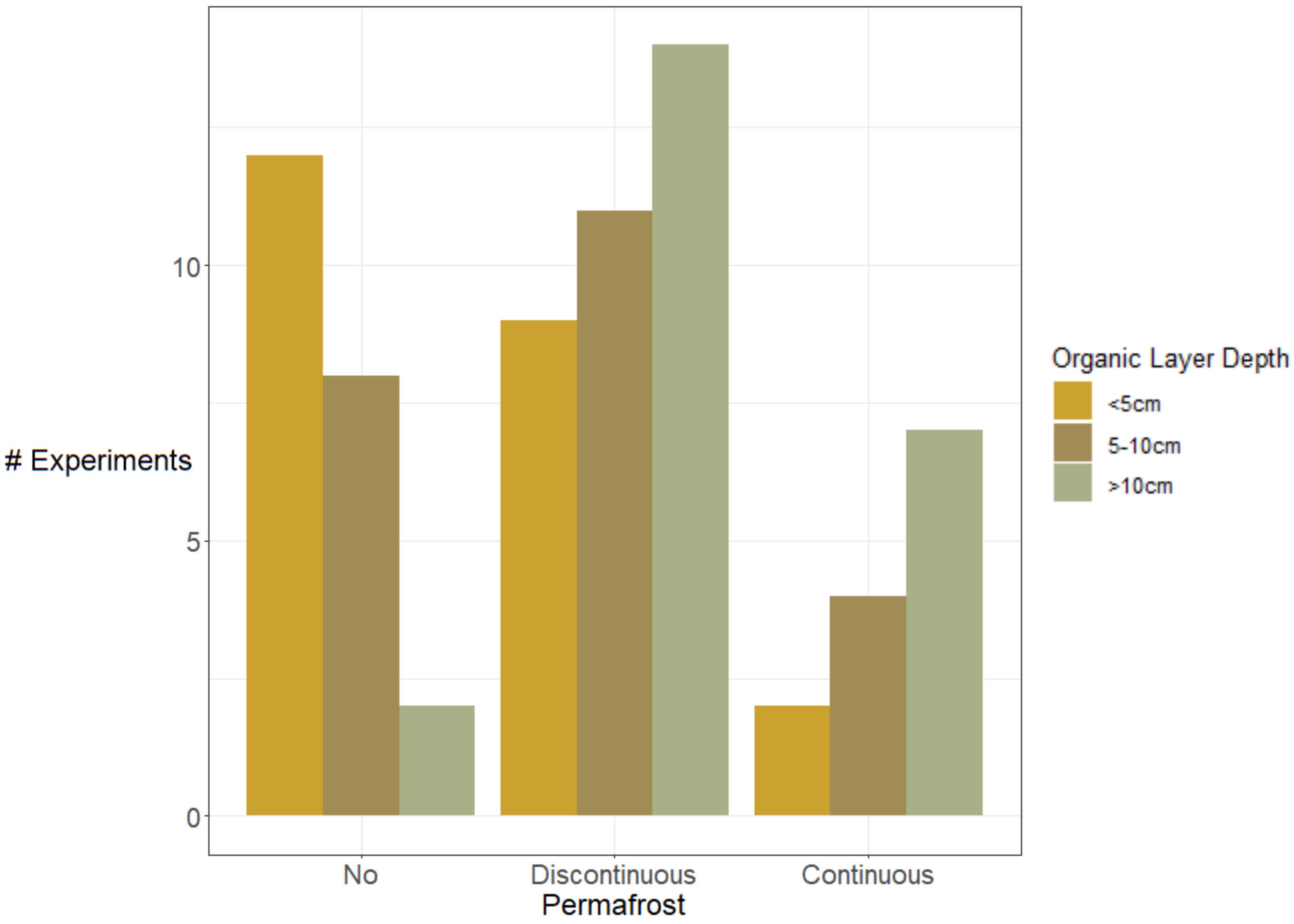


Results

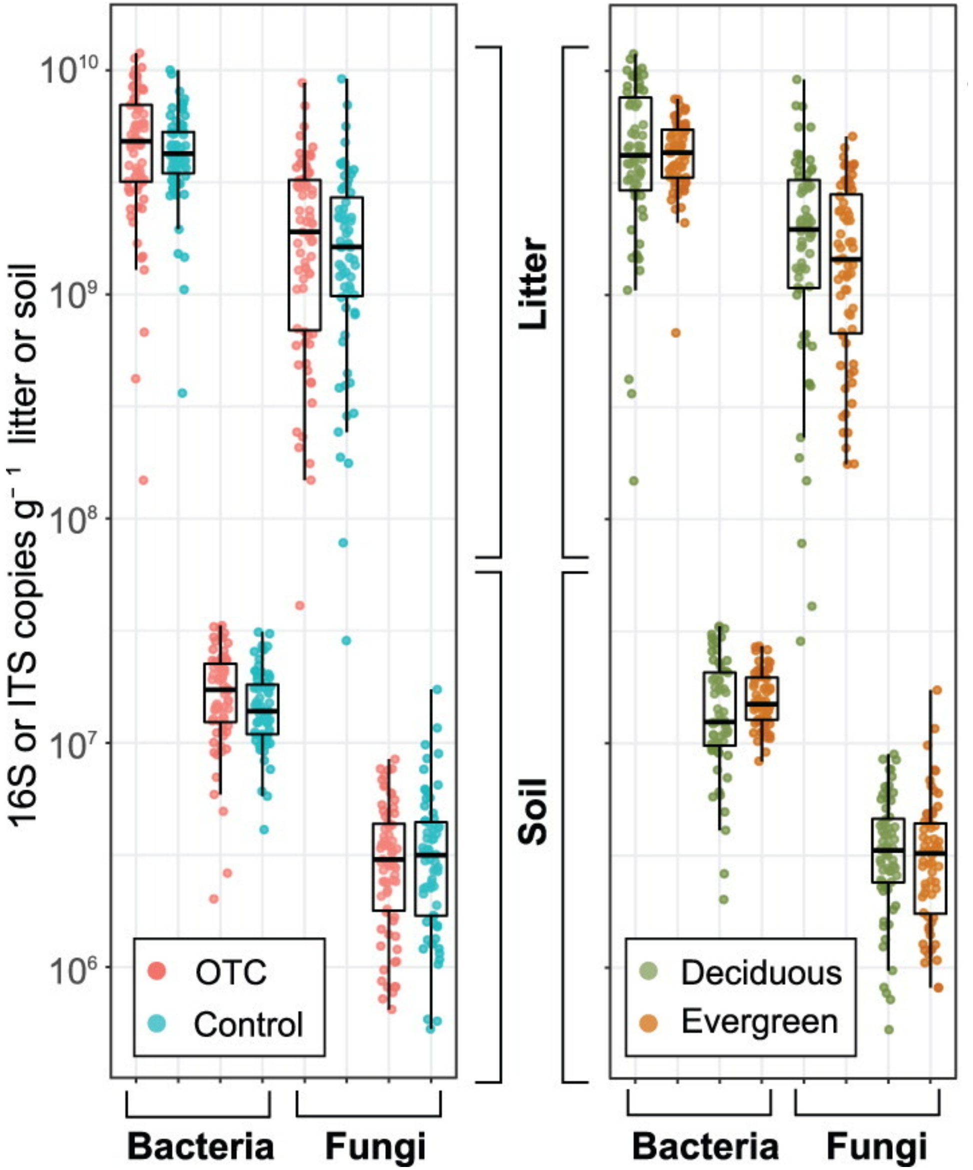


Site
SMD [95% CI]
ALA_1, 2016 4.15% -0.33 [-0.72, 0.06]
ALA_1, 2017 4.03% -0.68 [-1.08, -0.27]
ALA_1, 2018 1.40% -0.61 [-1.46, 0.24]
ALA_5, 2018 0.47% 0.49 [-0.77, 1.74]
ALA_6, 2017 0.53% 0.33 [-0.91, 1.58]
ALA_6, 2018 0.49% 0.08 [-1.23, 1.40]
ALA_8, 2017 0.42% 1.36 [-0.02, 2.73]
ALA_13, 2021 1.18% -0.19 [-0.60, 0.21]
CAN_2, 2011 1.54% -0.01 [-0.60, 0.58]
CAN_2, 2012 1.18% 0.68 [-0.16, 1.51]
CAN_3, 2011 1.02% -0.04 [-0.79, 0.70]
CAN_3, 2012 0.55% -0.21 [-1.50, 1.08]
CAN_4, 2011 0.98% -0.29 [-1.17, 0.59]
CAN_4, 2012 1.08% 0.05 [-0.75, 0.85]
CAN_5, 2019 0.71% 0.49 [-0.40, 1.38]
CHI_4, 2014 11.47% -0.19 [-0.41, 0.03]
CHI_4, 2015 11.43% -0.10 [-0.33, 0.12]
GRE_1, 2014 1.07% -0.57 [-1.09, -0.06]
GRE_2, 2014 1.11% 0.18 [-0.29, 0.65]
GRE_3, 2014 1.08% 0.09 [-0.42, 0.59]
NOR_2, 2000 0.21% -1.11 [-3.22, 1.00]
NOR_3, 2000 0.19% -1.61 [-3.87, 0.64]
NOR_4, 2000 0.33% 0.30 [-1.31, 1.91]
NOR_5, 2000 0.33% -0.04 [-1.64, 1.56]
NOR_6, 2020 0.37% -1.49 [-2.98, -0.01]
NOR_7, 2020 0.31% 0.77 [-0.89, 2.43]
NOR_8, 2020 0.27% -0.48 [-2.30, 1.33]
NOR_13, 2000 0.33% -0.06 [-1.66, 1.54]
NOR_14, 2000 0.33% -0.01 [-1.61, 1.59]
NOR_15, 2000 0.33% 0.11 [-1.49, 1.71]
NOR_16, 2000 0.33% -0.37 [-1.98, 1.25]
RUS_1, 2012 0.55% 0.23 [-1.04, 1.50]
RUS_1, 2013 0.63% -0.42 [-1.58, 0.73]
RUS_1, 2014 0.48% 0.09 [-1.29, 1.48]
RUS_2, 2012 1.00% 0.84 [-0.05, 1.73]
RUS_2, 2013 1.17% 0.80 [0.04, 1.57]
RUS_2, 2014 0.30% -1.69 [-3.55, 0.18]
RUS_3, 2012 1.11% 0.72 [-0.13, 1.57]
RUS_3, 2013 1.39% 0.70 [0.05, 1.34]
SVA_9, 2018 1.00% -0.54 [-1.12, 0.03]
SWE_1, 2017 2.27% -0.90 [-1.50, -0.29]
SWE_1, 2018 2.34% -1.05 [-1.64, -0.46]
SWE_1, 2019 0.62% -0.86 [-2.16, 0.43]
SWE_1, 2022 2.68% -0.85 [-1.38, -0.32]
SWE_2, 2017 2.21% -0.90 [-1.49, -0.31]
SWE_2, 2018 1.90% -0.90 [-1.57, -0.24]
SWE_2, 2019 0.51% -0.76 [-2.20, 0.67]
SWE_2, 2022 2.15% -1.41 [-2.01, -0.80]
SWE_3, 2017 2.93% -0.25 [-0.75, 0.26]
SWE_3, 2018 2.57% -0.57 [-1.14, -0.01]
SWE_3, 2019 0.64% -0.78 [-2.07, 0.51]
SWE_3, 2022 2.69% -0.83 [-1.37, -0.28]
SWE_4, 2017 1.89% -1.12 [-1.79, -0.44]
SWE_4, 2018 2.07% -1.39 [-2.02, -0.76]
SWE_4, 2019 0.58% -1.18 [-2.52, 0.16]
SWE_4, 2022 2.44% -1.11 [-1.66, -0.56]
SWE_5, 2017 1.67% 0.86 [0.11, 1.60]
SWE_5, 2018 2.82% 0.13 [-0.38, 0.64]
SWE_5, 2019 0.67% 0.20 [-1.04, 1.45]
SWE_5, 2022 2.85% 0.02 [-0.49, 0.52]
SWE_6, 2015 1.25% 0.16 [-0.18, 0.49]
SWE_12, 1999 0.45% 0.08 [-1.30, 1.47]
SWE_12, 2000 0.45% -0.11 [-1.50, 1.28]
SWE_13, 1999 0.41% 0.82 [-0.62, 2.27]
SWE_13, 2000 0.31% -1.11 [-2.83, 0.61]
SWE_14, 1999 0.45% -0.33 [-1.73, 1.06]
SWE_14, 2000 0.51% 0.69 [-0.59, 1.96]
SWE_15, 1999 0.42% -0.85 [-2.29, 0.60]
SWE_15, 2000 0.42% 0.83 [-0.62, 2.27]
RE Model 100% -0.15 [-0.34, 0.05]
-4
-2
0
2
4
Standardized Mean Difference

Permafrost - Organic Layer Depth

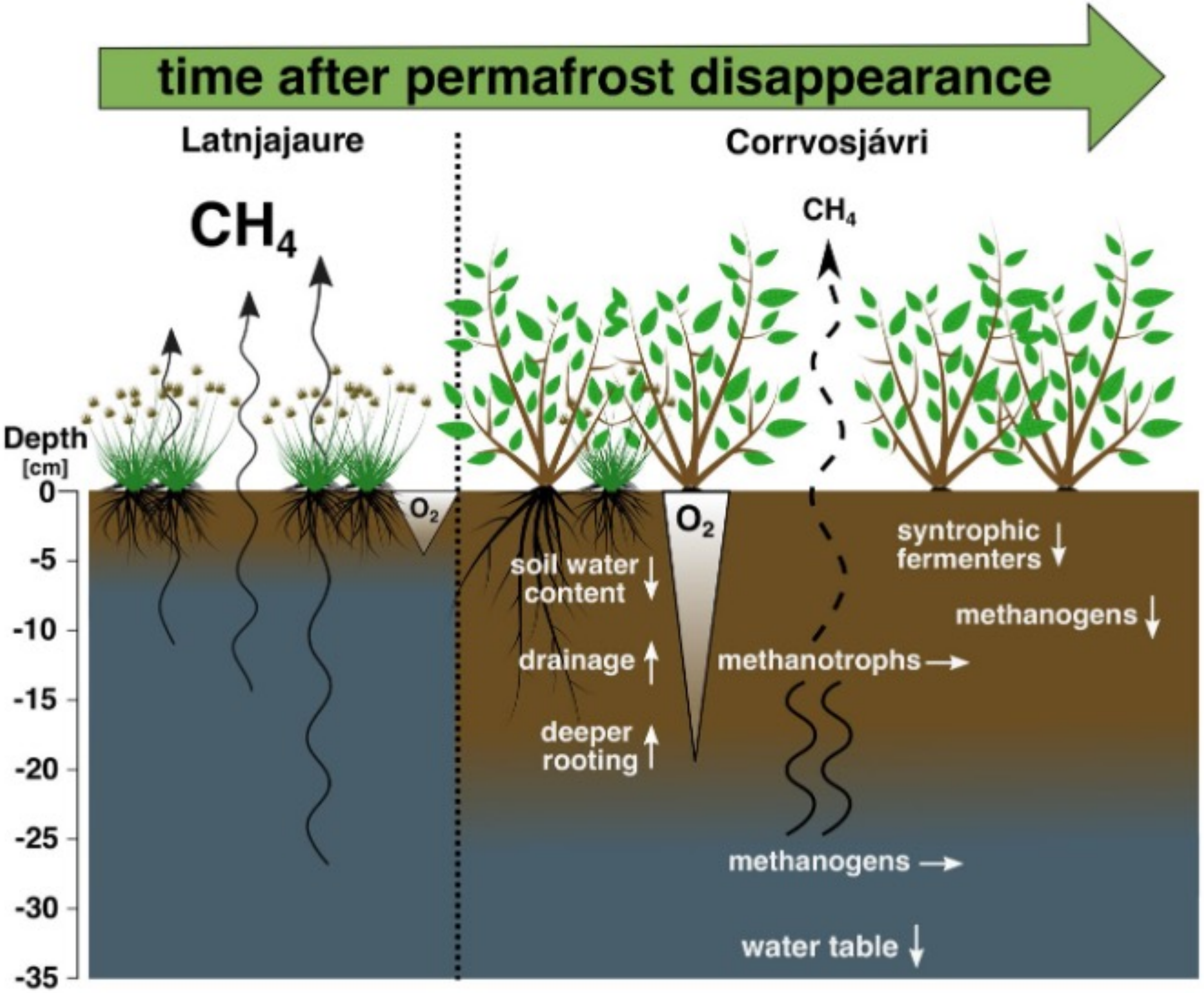


microbes



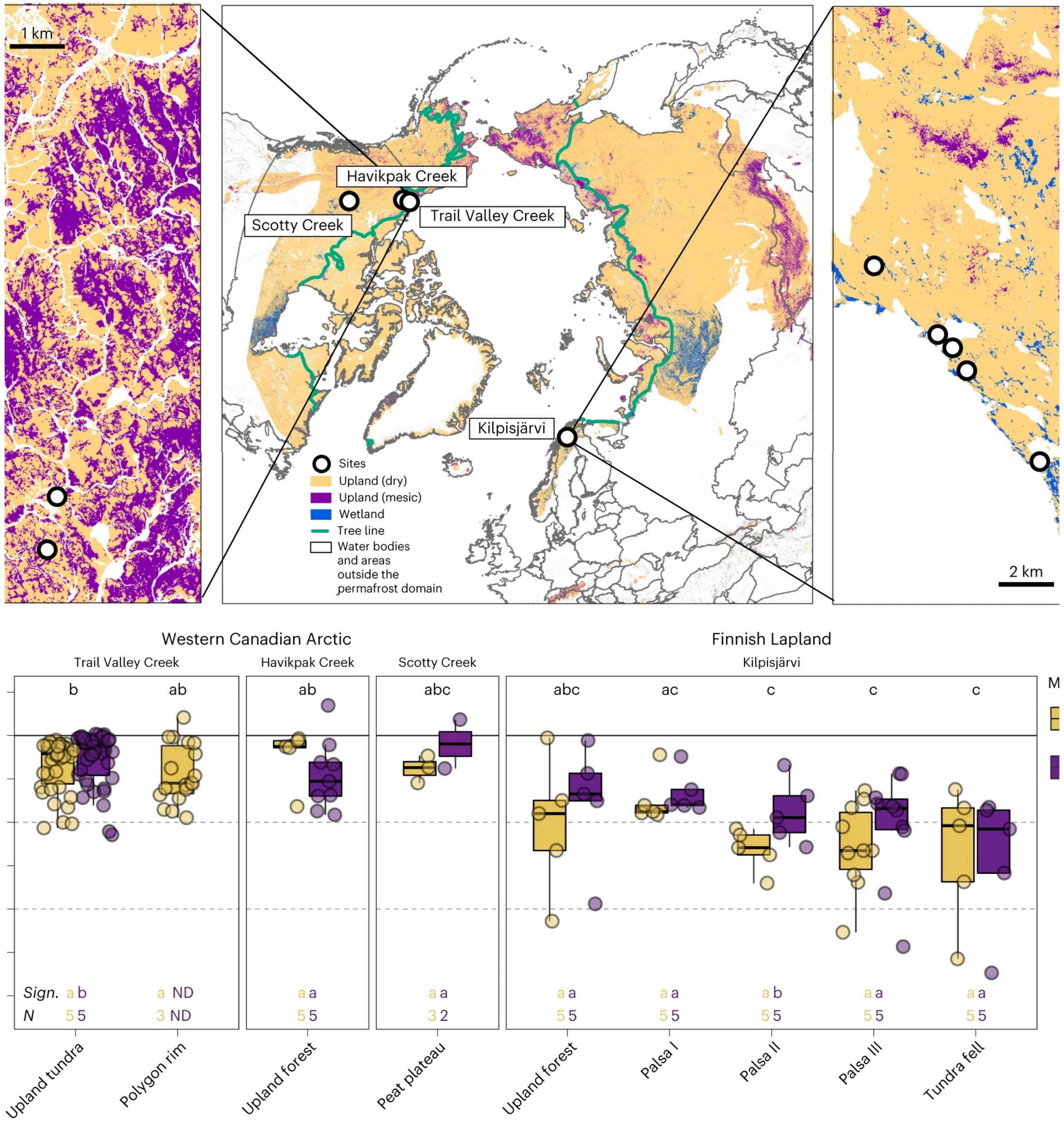
Jeanbille 2021

microbes



Keuschnig 2022

Dry Upland soils



Voigt 2023

CH4 – CO2

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