Lateral Carbon Transport Across a Permafrost Thaw Gradient

Kyla Drum[1], Cheristy P. Jones[1], Kainani Tacazon[2], Bailey Mullins[1], Claudia Guillot-Wallace[3], Kitty Becker[4], Lyreshka Castro Morales[1], M. Florencia Fahnestock[1], Ruth K. Varner[1], McKenzie Kuhn[1]

[1]University of New Hampshire, [2]Chapman University, [3]Macalester College, [4]Colorado State

Introduction

- Methane (CH_4) is a potent greenhouse gas with 28-34 times the global warming potential of carbon dioxide[1].
- CH_4 is produced in wetlands globally, including the Arctic.
- The Arctic is warming at least two times faster than the rest of the world[2].
- Climate warming leads to permafrost thaw, releasing previously stored carbon, expanding wetlands, and increasing lateral movement of water and carbon throughout the landscape.

Research Question

To what extent is methane concentration controlled by lateral carbon transport across a thaw gradient?

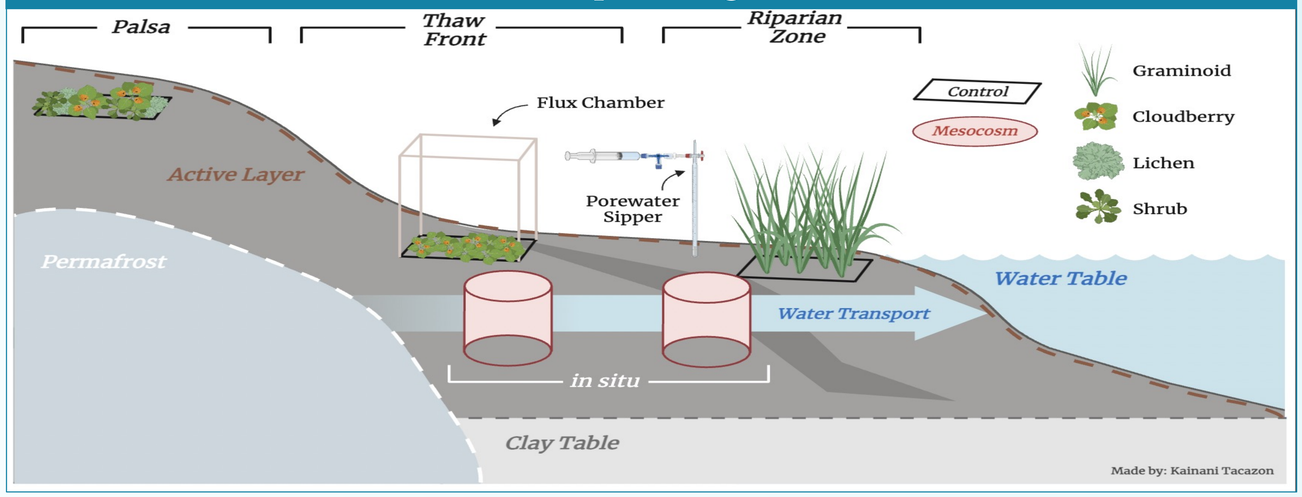
Study Design

- Stordalen Mire, in Arctic Sweden (68.20°N, 19.03°E).
- 60 cm collars were installed next to control plots to eliminate the lateral movement of water, and therefore dissolved carbon species through the ground.
- Plots were located along a thaw transect, including a recent thaw front and a riparian zone of a nearby lake.

Methods

- For porewater CH_4 samples, a stainless-steel tube was used to collect porewater followed by a headspace equilibrium technique (Righthand picture).
- Headspace gas was analyzed on a gas chromatograph with an FID detector at the Abisko Scientific Research Station.
- Dissolved Organic Carbon (DOC) and Specific UV Absorbance ($SUVA_{254}$) porewater was filtered through a pre-ashed 0.45 um filter and acidified with 2 M HCL.
- For Dissolved Inorganic Carbon (DIC) 25 mL of porewater was stored and acidified.
- For CO_2 and CH_4 fluxes, chambers were placed over control and mesocosm sites and measured using a LICOR gas analyzer (LI-7810).

Conceptual Diagram



Results: CH_4 and Carbon dynamics differ with the lateral flow.

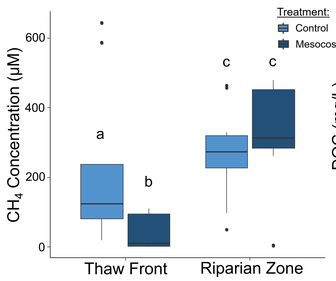


Figure 1: CH_4 concentrations at the thaw front and riparian zone for control plots and mesocosm sites. Control plots had higher concentrations at the thaw front ($p<0.01$), and no difference between plots in the riparian ($p=.09$). Concentrations were higher in the riparian zone than the thaw front ($p<0.001$). Difference letters indicate significant differences ($p<0.05$).

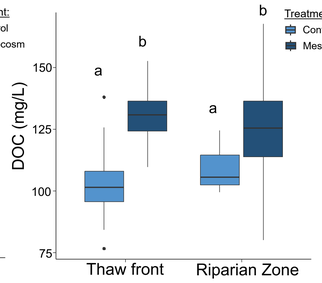


Figure 2: DOC concentrations at the thaw front and riparian zone for control plots and mesocosm sites. Concentrations were lower at control plots in riparian zone ($p=0.03$) and thaw front ($p<0.01$). Concentrations did not differ between ecosystem types ($p=0.9$). Difference letters indicate significant differences ($p<0.05$).

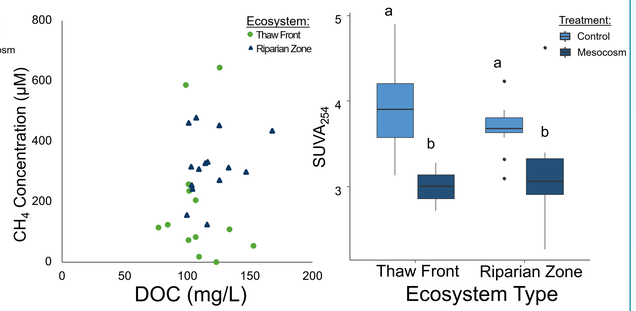


Figure 3: DOC concentrations compared to CH_4 concentrations in thaw front and riparian sites. There is no correlation between DOC and CH_4 concentrations at either ecosystem type.

Figure 4: $SUVA_{254}$ values at the thaw front and riparian zone for control plots and mesocosm sites. Values were higher at control plots in the riparian zone ($p=0.02$) and thaw front ($p=0.02$). $SUVA_{254}$ was not different between the riparian zone and thaw front ($p=0.3$). Difference letters indicate significant differences ($p<0.05$).

Conclusion

- Within the thaw zone, there were lower concentrations of CH_4 in the mesocosms than the controls, however there was no difference in the riparian zone.
- Lower DOC concentrations were found in the control plots than mesocosm plots in both the thaw front and riparian zone, potentially due to dilution in the control plots.
- The lower $SUVA_{254}$ values found at the mesocosm plots of both the thaw front and riparian zone indicate higher bio-availability of the DOC in mesocosm plots.
- DOC was less biodegradable in the thaw front than the riparian zone.
- There was no observed correlation between CH_4 and DOC.
- Overall, despite the higher concentrations and bio-availability of DOC found in mesocosm plots, CH_4 was observed to be higher in control plots at the thaw front. These results suggest that DOC is not the primary control on CH_4 production in soils, and that dissolved CH_4 may be transported to the thaw front.

Next Steps

- Analyze DIC concentrations in porewater to enhance understanding on carbon dynamics across a thaw gradient both in the absence and presence of lateral transport.
- Calculate vertical CH_4 and CO_2 fluxes from LICOR data to supplement porewater CH_4 results.

References

[1]*Methane Management: The Challenge*. UNECE. (2023). https://unece.org/challenges

[2]Rantanen, M., Karpechko, A., Lipponen, A., Nordling, K., Hyvarinen, O., Ruosteenoja, K., Vihma, T., Laaksonen, A. 2022. The Arctic has warmed nearly four times faster than the globe since 1979. *Nature 1:168*

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