Carbon trace gas dynamics in subarctic lakes

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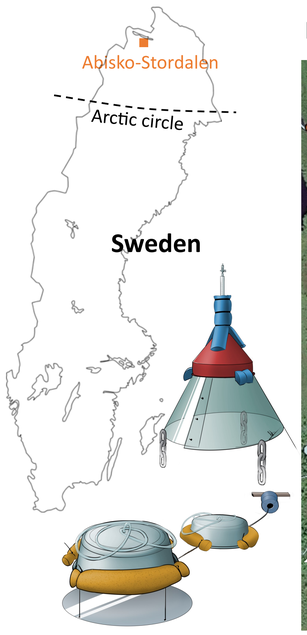
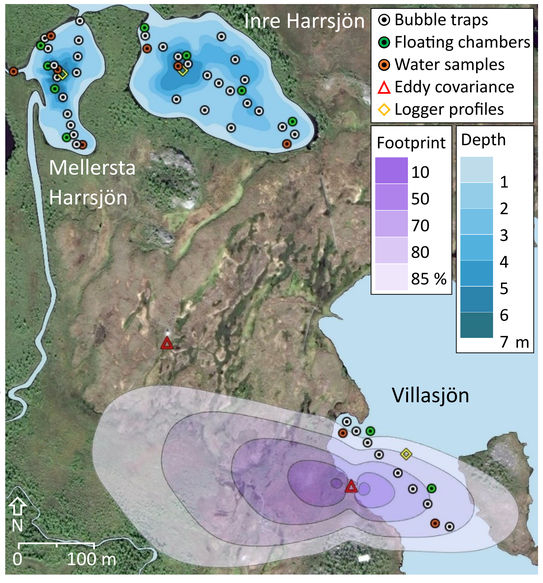
Quantifying climate forcing trace gas emissions from subarctic lakes

Northern lakes are an important source of radiatively active trace gases methane (CH_4) and carbon dioxide (CO_2) to the atmosphere. A significant portion of the annual emissions occur in spring after prolonged ice cover, but this flux is currently neither well constrained nor fully understood. Here we present a detailed annual carbon gas budget for three subarctic lakes in northern Sweden from a unique, long-term monitoring program running between 2009 and 2017.



Field site: the Stordalen mire complex



Our measurements are focused on three small (0.2 km² total) shallow (<7 m) subarctic lakes situated in peatland underlain by discontinuous permafrost:

- On the lakes: 10 diffusion chamber pairs, 38 bubble traps (CH_4 fluxes)
- On shore: tower for eddy covariance and local meteorology (energy balance)
- In the water: sampling of dissolved CO_2, CH_4. Submerged sensors for temperature, dissolved oxygen, specific conductivity and water level
- In the lab: gas concentration measurements on a GC (CH_4) and IRGA (CO_2)

References

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Acknowledgements

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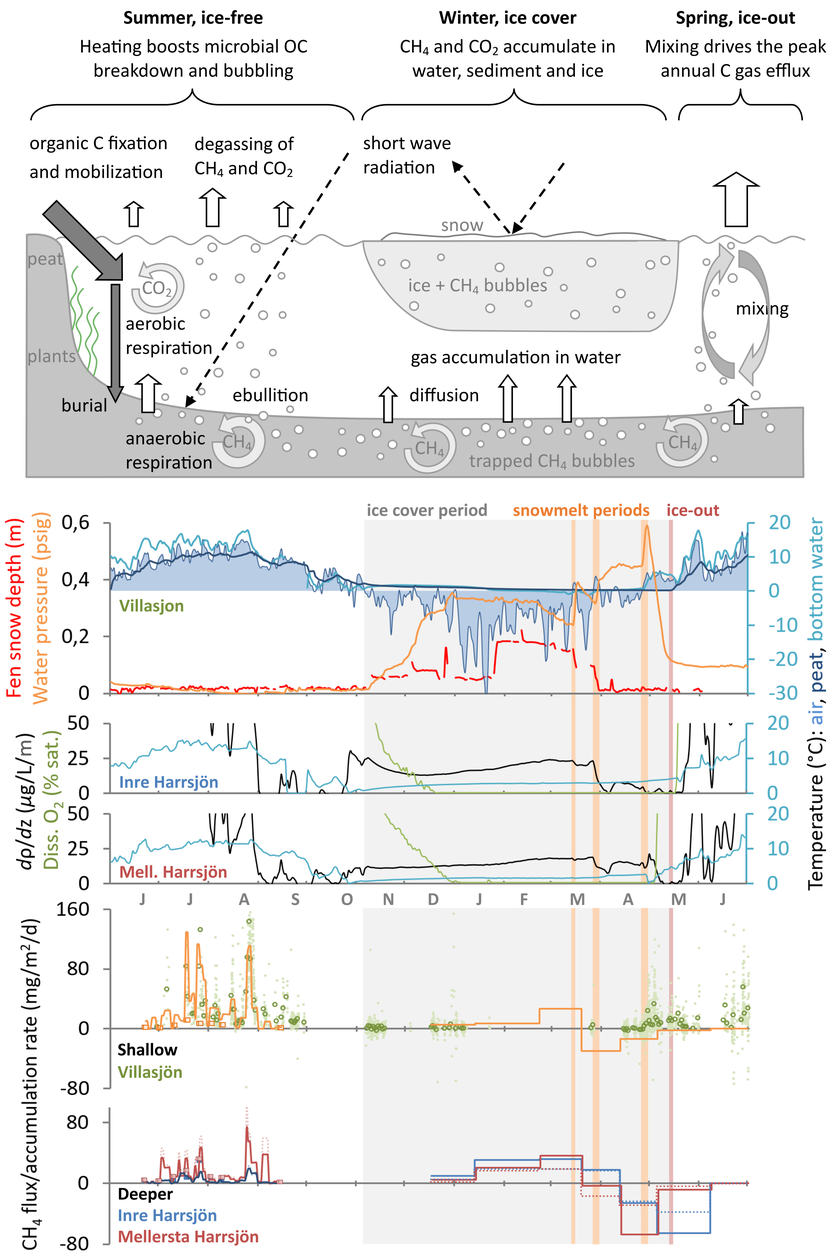
Seasonal variability of Stordalen lake methane fluxes (2015-2016)

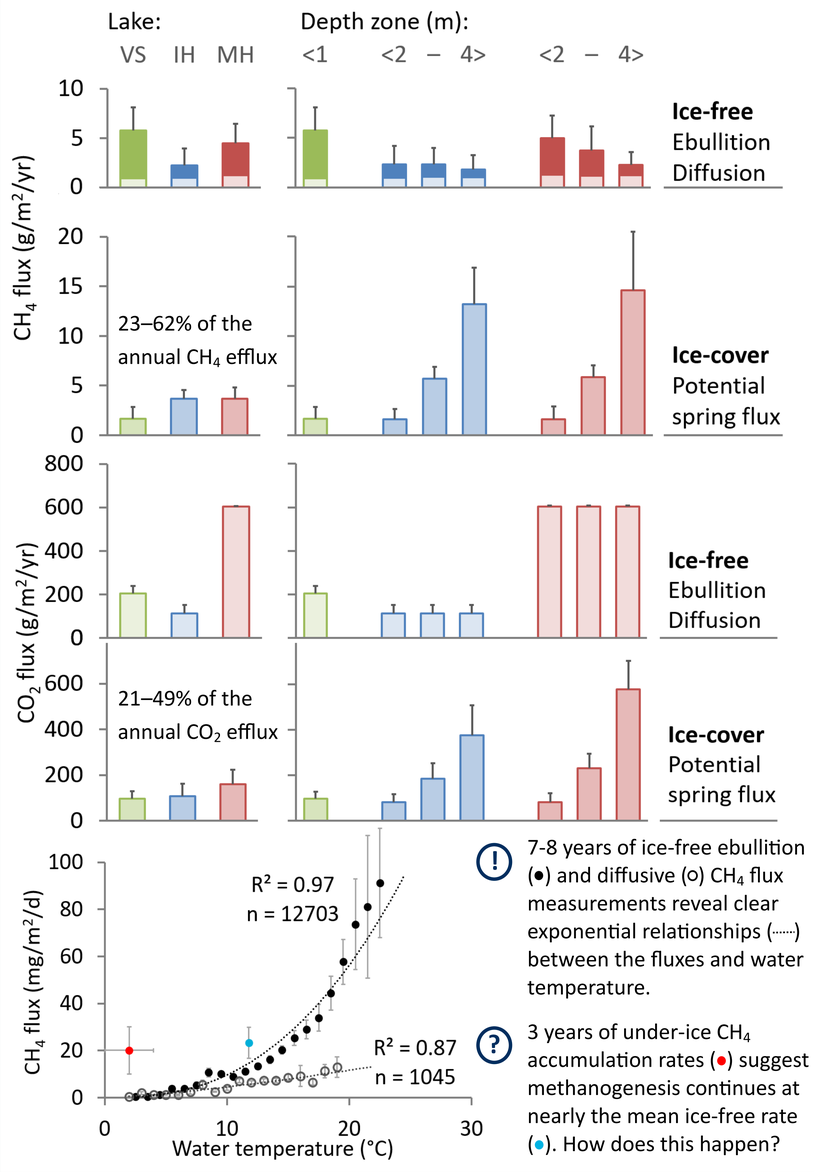


Top figure: schematic of seasonal processes affecting the carbon gas flux. Middle figure: 2015-2016 meteorology of the mire and lakes. Bottom figure: 2015-2016 CH_4 fluxes and accumulation rates. Villasjön: half hourly (close symbols) and daily mean (open symbols) eddy covariance fluxes (green circles), bubble fluxes / acc.rates (lines), chamber fluxes (bars). Inre and Mellersta Harrsjön: depth-averaged fluxes (solid lines) and shallows only (dotted lines).

(!) In 2016 most dissolved carbon gas disappeared well before ice-off, when stratification broke up, due to meltwater advection following early snowmelt.

Multi-year measurements of carbon gas production and emission

Most CH_4 is emitted from warm shallow sediments in summer as bubbles. Under ice, most gas builds up at depths >4m, though they only cover <12% of lake surface area.



(!) 7-8 years of ice-free ebullition (•) and diffusive (o) CH_4 flux measurements reveal clear exponential relationships (·····) between the fluxes and water temperature.

(?) 3 years of under-ice CH_4 accumulation rates (•) suggest methanogenesis continues at nearly the mean ice-free rate (•). How does this happen?

Conclusions

- Most CH_4 is released via the ebullition pathway in two out of the three study lakes
- Both ice-free CH_4 emission pathways show a strong dependence on temperature
- The process that generates large quantities of carbon gas under the ice remains unknown, and it is unclear what fraction of this pool reaches the atmosphere