Physical and biogeochemical controls on lake carbon gas emissions in spring

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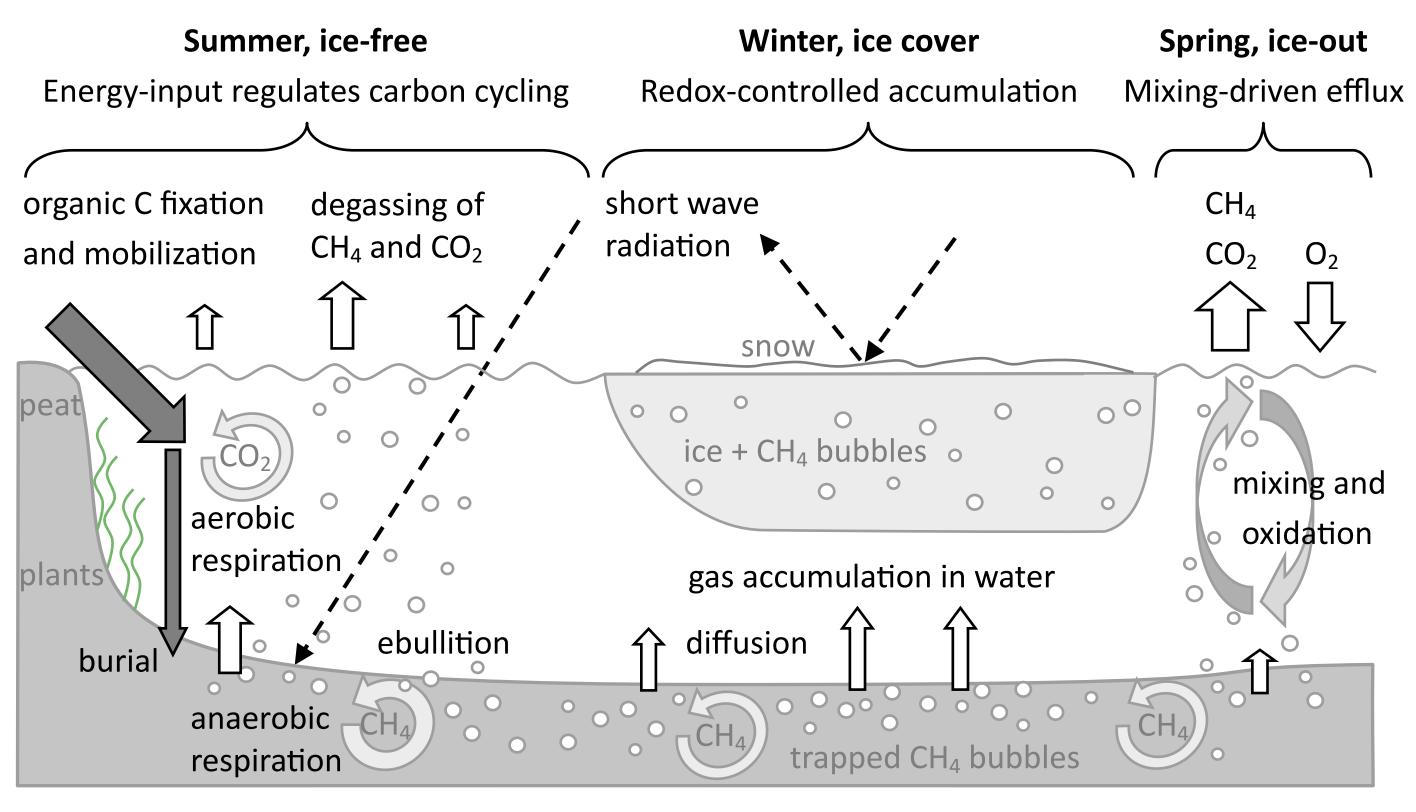
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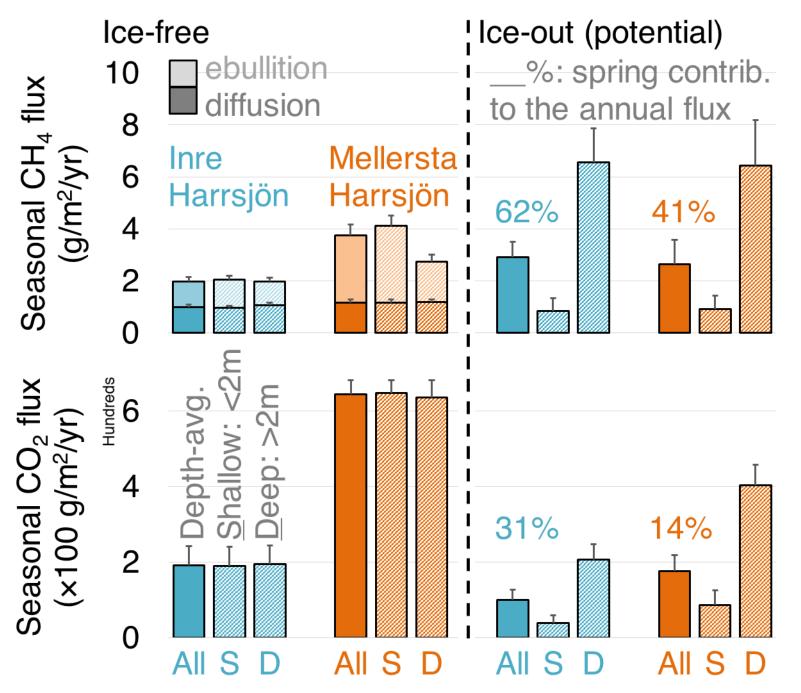


Quantifying climate forcing trace gas emissions from subarctic lakes

Northern lakes are an important source of radiatively active trace gases methane (CH₄) and carbon dioxide (CO₂) to the atmosphere. Significant emissions can occur in spring, but limited data has led to poor representation in regional budgets. Here we present a detailed study of winter and spring C dynamics for two subarctic lakes.

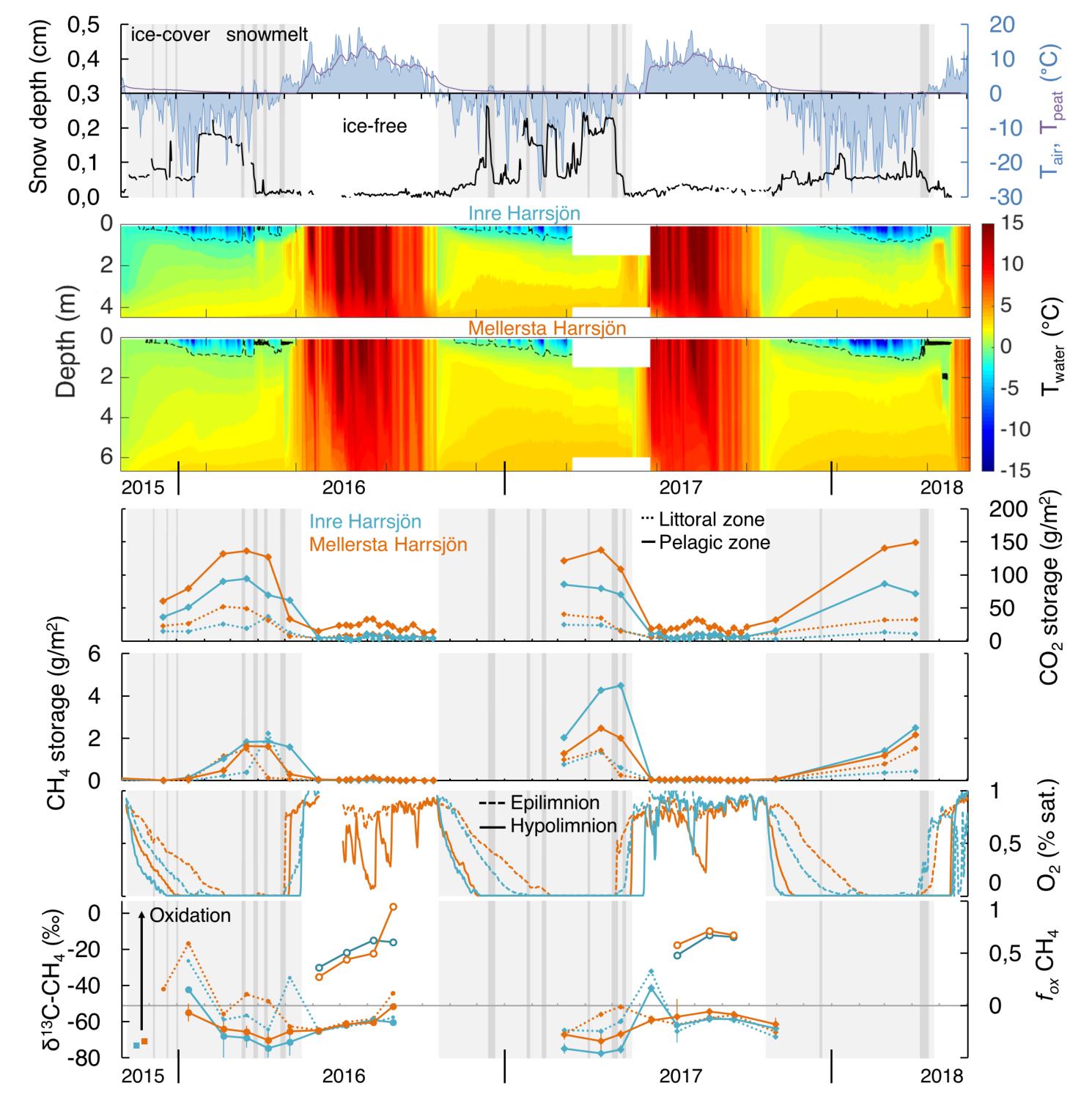


A significant part of annual lake C emissions takes place in spring:

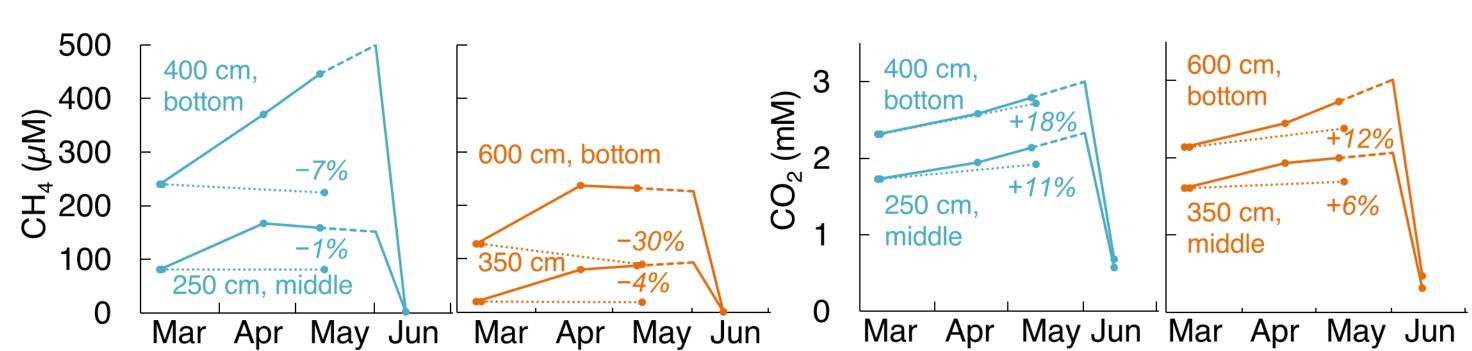


- Summer: most CH₄ is emitted from shallow parts of the lakes
- Winter: most CH₄ accumulates in the deeper parts of the lakes
- Ice-free season CO₂ emissions dominate the annual C budget
- CO₂ flux independent of depth
- Winter: most CO₂ accumulates in the deeper parts of the lakes

Substantial accumulation of CO₂ and CH₄ at the lake deepest points:

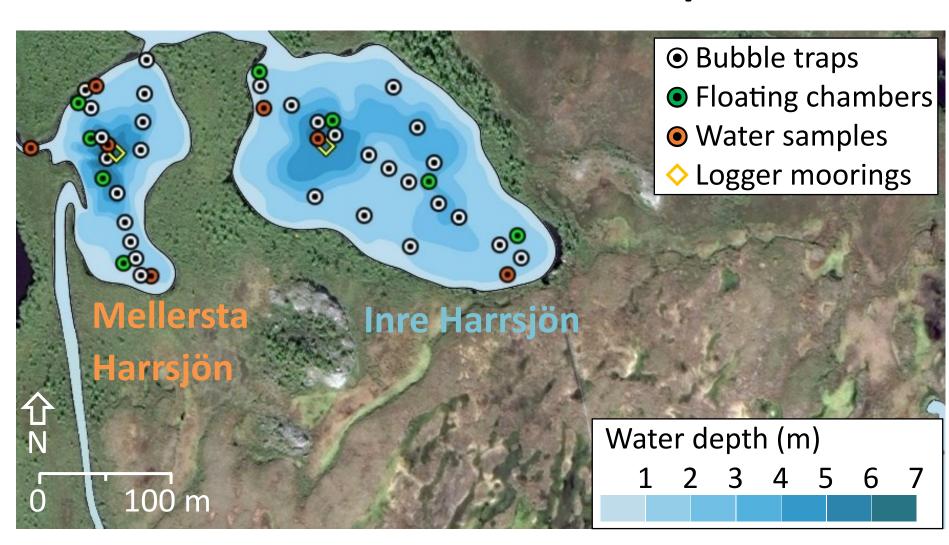


No evidence for water column methanogenesis under ice:



In situ incubations under ice (dotted lines) show 1−30% decrease of CH₄ over time

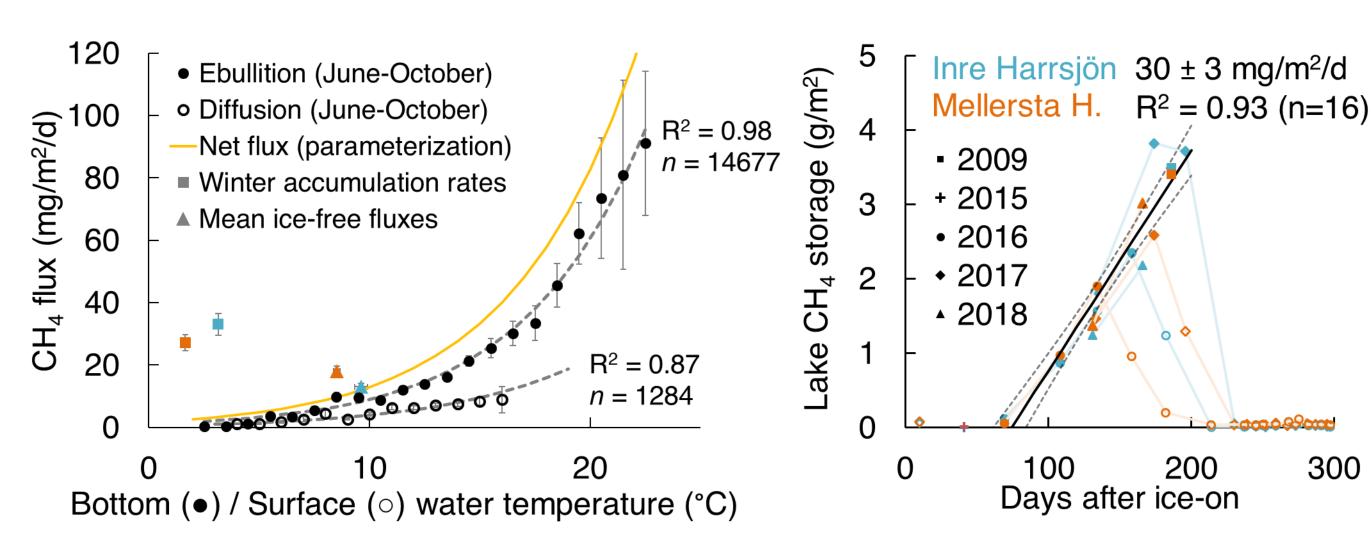
Field site: the Stordalen Mire complex



Our long-term measurement program (2009–2018) is focused on two small (0.01 km²) shallow (<7 m) subarctic lakes situated in peatland underlain by discontinuous permafrost:

- Manual sampling: 8 surface flux chamber pairs, 30 bubble traps (CH₄ fluxes), water sampling (aqueous CH₄, CO₂)
- Submerged sensors for temperature (HOBO U22), conductivity (HOBO U24) and dissolved O₂ (MiniDOT)
- Lab: pCH₄ (GC), pCO₂ (IRGA); δ^{13} C-CH₄ (GC-IRMS)

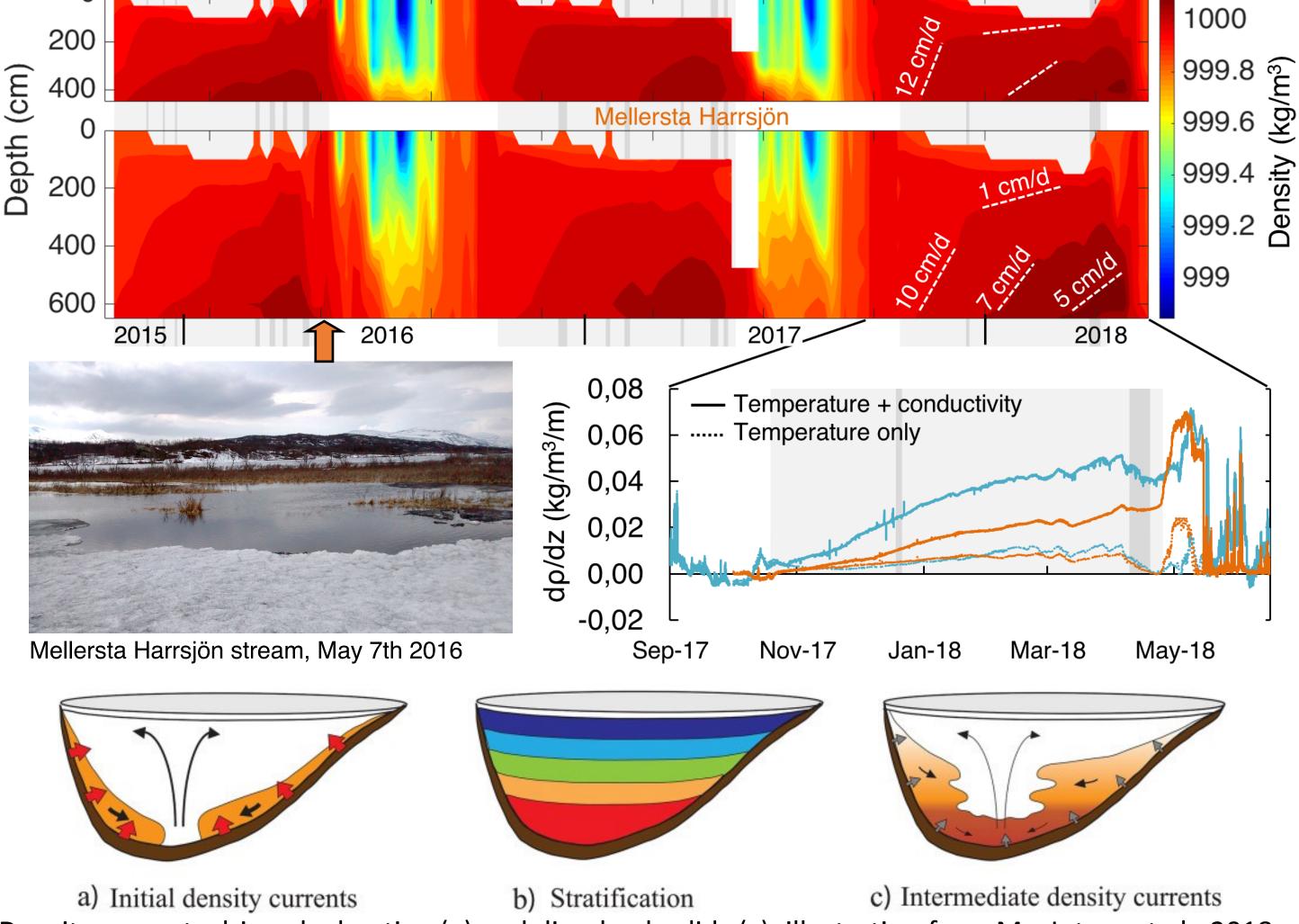
Predictors differ for CH₄ emission (ice-free) and storage (ice-cover):



- Summer CH₄ fluxes strongly depended on energy input for both emission pathways
- Winter CH₄ accumulation depended on the length of the ice-cover / anoxic period

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Dissolved solids and snowmelt events control winter stratification:



Density currents driven by heating (a) and dissolved solids (c): illustration from MacIntyre et al., 2018

- Upward motion of isopycnals suggests density currents drive under-ice circulation
- At ice-off, stratification is almost entirely due to accumulated dissolved solids
- Snowmelt events can oxygenate part of the water column before ice-off
 - What fraction of accumulated CH₄ is microbially oxidized in spring? How will shorter ice-cover seasons affect C gas emissions from northern lakes?

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Acknowledgements

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