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Methane isotopic signature of gas bubbles in permafrost winter lake ice: a tool for quantifying variable oxidation levels

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Methane (CH_4) is a strong greenhouse gas and its atmospheric mixing ratio has strongly increased since pre-industrial times. This increase was primarily due to emissions from anthropogenic sources, but there is growing concern about possible feedbacks of natural sources in a changing climate. Thawing of permafrost areas in the Arctic is considered as an important feedback, since the Arctic region undergoes the fastest climate change and hosts large carbon stocks. Subarctic lakes are considered as "hotspots" for CH_4 emissions, but the role of the ice cover during the winter period is not well understood to date.

Here, we present measurements of CH_4 mixing ratio and δ^{13}C-CH_4 in 4 types of bubbles identified in subarctic lake ice covers located in a sporadic or discontinuous permafrost area. Our analysis reveals that different bubble types contain CH_4 with different, specific isotopic signatures. The evolution of mixing ratio and δ^{13}C-CH_4 suggest that oxidation of dissolved CH_4 is the most important process determining the isotopic composition of CH_4 in bubbles. This results from gas exsolution occurring during the ice growth process. A first estimate of the CH_4 oxidation budget (mean = 0.12 mg CH_4 m^{-2} d^{-1}) enables to quantify the impact of the ice cover on CH_4 emissions from subartic lakes.

The increased exchange time between gases coming from the sediments and the water column, due to the capping effect of the lake ice cover, reduces the amount of CH_4 released "as is" and favours its oxidation into carbon dioxide; the latter being further added to the HCO_3^- pool through the carbonate equilibration reactions.