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Methane and CO_2 pathways and emissions in a small Swiss Lake: A case study linking paleolimnology, land use and carbon turnover

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Methane from freshwaters contributes ∼20% to the total global atmospheric methane emissions (excluding wetlands), with about half attributed to bubble release (ebullition). Methane is an important greenhouse gas, whose global warming potential is 28 times greater than carbon dioxide. With positive correlations to temperature and eutrophication, ebullition rates from lakes are expected to be exacerbated with a warming climate and increased nutrient loading. Little work, however, has been performed on the effect on methane formation and transport on lake ecology and carbon turnover, and the eutrophication-methane feedback mechanisms. We report a study of methane and CO_2 formation, transport and emissions on Lake Soppen – a small, glacially-formed lake located in Canton Lucerne (Switzerland). Extensively studied in the last decades, Lake Soppen has experienced increasing eutrophication in the past centuries. Using current monitoring results, combined with published paleolimnological indicators and system analysis, we report present methane and CO_2 production rates, pathways and emissions, as well as an estimation of the beginning of methane ebullition in the lake's history. Linked with a historical increase in sedimentation rates, the beginning of methane bubble emission and associated eutrophication is likely responsible for a dramatic shift in the lake benthic fauna populations, with consequences to the trophic carbon transport. We hypothesize that the time when sediment methane bubble release begins represents a significant tipping point in lake trophic status, and in Lake Soppen is likely linked to significant land use changes in the small (1.6 km2), largely agricultural watershed. Finally, in this case study, we quantify the methane and CO_2 transport mechanisms and fate in Lake Soppen, with an emphasis on refining the carbon balance, turnover, and estimating basin-wide CO_2 and methane emissions.