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Spatial-temporal carbon balance of small shallow lakes in the temperate zone

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Inland waters – such as lakes, streams, ponds, and reservoirs – release the greenhouse gases methane (CH_4) and carbon dioxide (CO_2) into the atmosphere. In contrast, studies suggest that 20 % of the terrestrial carbon sinks are presently being sequestered in inland waters. Due to their high number and a higher metabolic activity, small inland waters (< 1 km^2) are a particularly important source of methane and carbon dioxide on the landscape scale. Until now, only little is known about temporal and spatial dynamics of carbon fluxes and CH_4-emissions in these small, epilimnetic lakes. While a few studies have assessed fluxes in these systems in the boreal zone, small lakes of the temperate zone are currently not well studied. Shallow lakes were found to be warmer and more productive and have a shorter residence times of water. In the temperate zone, these lakes are even warmer than the ones in the boreal zone, having more precipitation as well as more evaporation and a higher carbon turnover due to more labile organic matter.

To address this knowledge gap, we determined the CO_2 and CH_4 fluxes in two of these small and shallow temperate lake systems along high spatial resolution transects over annual cycles. The lake 'Windsborn' (max. depth 1.5 m, size 1.4 ha), a crater lake in western Germany, has a small catchment of only 3 ha and no surficial inflows or relevant groundwater inflows, so it qualified for understanding the environmental factors and processes controlling the fluxes within the lake. The second lake 'Heideweiher' (max. depth 1 m, size 1.5 ha) has no surficial inflows as well, but low groundwater inflows. Fluxes of CO_2 were measured using plastic floating chambers with CO_2 sensors, which were placed in transects, covering depth gradients from the shore to the center of the lake. Diffusive fluxes of CH_4 were measured manually over 24 h campaigns, biweekly with the same chambers. The contribution of ebullition was also quantified manually every fortnight and using funnels. We also analyzed the surface water CO_2 and CH_4 concentration across the open water area of the lakes. Finally, the measured meteorological weather station data and lake characteristics were associated with flux and surface concentration data.

As expected, the lakes seems to be a source for CO_2 and CH_4 on the annual scale but with strong seasonal differences. Emissions increased from spring to summer and decreased after fall storms. In the summer months, the CO_2 emissions show a strong daily dynamics, with temporal phases of CO_2 uptake. The emissions also showed strong spatially variability, especially between shores and open areas. Shallow areas can be referred to as 'hot spots' of CO_2, surprisingly the center area showed significantly higher CH_4 emissions than the shore areas. Thus, this study shows relevance to consider the spatio-temporal variability of CO_2 and CH_4 emissions and helps to understand the flux regulation as well as possible feedbacks to climate change in shallow lakes.