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Surface water methane super-saturation and emission in Lake Lugano, southern Switzerland

Jan Blees (1), Helge Niemann (1), Markus Erne (1), Marco Simona (2), and Moritz F. Lehmann (1)

(1) University of Basel, Institute of Environmental Geosciences, Switzerland (jan.blees@psi.ch), (2) University of Applied Sciences of Southern Switzerland, Institute of Earth Sciences, Switzerland

Large amounts of greenhouse gases are produced in anoxic aquatic environments. Emission of these greenhouse gases to the atmosphere depends on their turbulent diffusion across the water – air boundary, which in turn depends on the concentrations within the boundary layers. We measured methane concentrations in the surface water of the northern basin of Lake Lugano in spring and autumn, and calculated diffusive fluxes to the atmosphere, using three different relationships for the parameterisation of the transfer velocity, taking into account temperature and wind effects. Surface water concentrations always exceeded atmospheric equilibrium concentration, and increased from 16 nmol L^{-1} in May to 45 nmol L^{-1} in October, indicating CH_4 accumulation in the surface mixed layer during summer. Calculated CH_4 fluxes were highly variable in space and time. As a result of the higher surface water CH_4 concentration and cooling of the surface boundary layer, resulting in increased buoyancy turbulence, the diffusive flux was highest in October (97 μmol m^{-2} d^{-1}, compared to 7 μmol m^{-2} d^{-1} in May). The observed concentration profiles indicate that mixed layer CH_4 accumulation derives from a near-surface source, and cannot be explained by the diffusive supply of CH_4 from the large deep-water CH_4 pool in the anoxic hypolimnion, where CH_4 oxidation at the redox transition zone consumes CH_4 effectively. Our study confirms that lake environments can act as a significant terrestrial source for atmospheric methane, despite efficient microbial CH_4 oxidation in the hypolimnion. The fact that the magnitude of the observed total CH_4 flux increases during the productive period between spring (409 mol d^{-1}) and autumn (968 mol d^{-1}) suggests links between methane evasion and the annual biological cycle, yet wind and temperature forcing of the surface mixed layer must play an equally important role for lacustrine methane emission.