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Spatio-temporal variability of lake methane fluxes and its influence on annual estimates

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Lakes are major sources of methane (CH4) to the atmosphere and it has been shown that lakes contribute significantly to the global CH4 budget. However, the data behind these global estimates are only snapshots in time and space and they typically lack information on spatial and temporal variability of fluxes which can potentially lead to biased estimates. Recent studies have shown that diffusive flux, gas exchange velocity (k), ebullition and concentration of CH4 in the surface water can vary significantly in space within lakes. CH4 fluxes can also change at a broad range of temporal scales in response to seasons, temperature, lake mixing events, short term weather events like pressure variations and diel cycles. We sampled CH4 fluxes and surface water concentrations from three lakes of differing characteristics in southwest Sweden over two annual cycles, approximately every 2 weeks from April to October 2012 and from April to November 2013. CH4 fluxes were measured using floating chambers distributed in the lakes based on depth categories and dissolved CH4 concentrations were determined by a headspace equilibration method. We observed significant differences in CH4 concentration, diffusion, ebullition and total fluxes between and within the lakes. The fluxes increased exponentially with temperature in all three lakes and water temperature, for example, explained 53-78% of variations in total fluxes in the lakes. Based on our data which relied on improved spatial and temporal information, we demonstrate that measurements which do not take into account of the spatial variability in the lakes could substantially bias the whole lake estimates. For instance, in one of the lakes, measurements from the central parts of the lake represented only 58% of our estimates from all chambers on an average. In addition, we consider how intensive sampling in one season of the year may affect the annual estimates due to the complex interaction of temperature, air pressure and lake mixing events on CH4 fluxes. For example, samples collected when the average air temperatures during chamber deployments were above 15 °C overestimated the total fluxes by 17-157% in all lakes when compared to averages from all measurement times.