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Diurnal patterns, seasonality and ebullition: A comparison of gap-filling strategies for closed-chamber CH4 measurements to derive a "best-practice" approach and give implications for future study designs

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Due to their operational simplicity allowing for spatially distinct measurements as well as their low costs and power consumption, manual closed-chamber systems are widely applied for obtaining ecosystem CH4 emissions. This is in particular the case for peatlands, which represent one of the most important hot spots for CH4 release but are also characterized by a high spatial heterogeneity, difficult access and often miss power supply. However, CH4 emission estimates based on periodically conducted chamber measurements are prone to a high temporal uncertainty, mainly related to the excessive filling of long gaps. Hence, diurnal and seasonal measurement frequencies as well as the applied gap-filling strategy are crucial factors, influencing the reliability of derived CH4 emissions.

To date no comprehensive analysis of the influence and interactions of these factors has been performed, nor does a widely accepted standard procedure exist. As a result, it remains largely unclear whether CH4 emission estimates, resulting from closed-chamber measurements are comparable or not and to which extent differences in measurement design and gap-filling add to the overall uncertainty of derived emission factors.

Here, we present continuous automatic closed-chamber CH4 measurements obtained during the year 2015 for two peatlands (Germany and Poland). These data is used to compare commonly applied gap-filling approaches. To do so, steady (diffusion and plant-mediated), ebullition and total CH4 fluxes were calculated and artificially grouped into weekly, fortnightly and monthly datasets. For each of these 3 x 3 datasets single and multiple daily samplings were randomly performed (n = 100). This procedure resulted in 100 times 3 x 3 x 2 sampling scenarios per measurement site. The sampling scenarios were then used to compare 11 different gap-filling strategies and analyse the influence of seasonal and diurnal measurement frequency on derived CH4 emissions. The performance of gap-filling strategies was evaluated by comparing modelled (gap-filled) with continuously measured CH4 fluxes and their resulting emission estimates.

Out of the different gap-filling strategies, simple interpolation methods and empirical modeling with environmental drivers (e.g. temperature and water table) were most suitable. Machine learning approaches (e.g., support vector machines and artificial neural networks) performed weaker, most likely because they require a greater amount of measured input data hardly being achieved by using discontinuous manual-chamber measurements. Compared to monthly or fortnightly measurements, the precision of CH4 emissions is substantially improved when applying a weekly measurement frequency. However, multiple measurements per day better reflect the average daily flux and thus reduce the potential bias of derived CH4 emissions. Thus, a lower seasonal measurement frequency could partially be compensated by enhancing the number of diurnal measurements.