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Cross-evaluating measurements of peatland methane emissions on microform and ecosystem scales – Effect of ecosystem heterogeneity on uncertainty of seasonal ecosystem budgets

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It is widely recognised that peatlands play a crucial role in the global carbon cycle. However, large uncertainties remain regarding the strength of their functions as sources or sinks of carbonaceous trace gases. In addition to the considerable gaps in our mechanistic understanding of carbon cycle processes in peatlands and relevant metrological difficulties (e.g., Forbrich et al. 2010), geospatial problems on multiple scales are major causes of uncertainty.

Here, we present a cross-evaluation of measurements of peatland methane emissions on microform and ecosystem (mesotope) scales. Microform-scale measurements were performed by a closed-chamber approach while ecosystem-scale measurements were performed by the eddy covariance method. The investigations were conducted over the vegetation period (May-September) 2007 at the oligotrophic mire complex Salmisuo in Eastern Finland (62.46°N, 30.58°E), which is characterized by a pronounced small-scale (0.1 m – 10 m) heterogeneity of the microtopography. Hummocks are elevated microforms with the lowest water level, hollows are depressed microforms with the highest water level, and lawns are intermediate microforms. For up- and downscaling between the microform and ecosystem scales, we combined surface classification based on high-resolution aerial photography (Becker et al. 2008) with analytical eddy covariance footprint modeling (Kormann et al. 2001). Diurnal and day-to-day variability of eddy covariance methane fluxes could be sufficiently explained by empirical modeling only if the varying microform composition in the eddy covariance footprint over time was explicitly considered. Consequently, short-term methane emission budgets were partly seriously disturbed by sensor location biases (Schmid and Lloyd 1999) due to prevailing measurements from a certain wind direction over short integration periods. However, when integrating the fluxes over the vegetation period, the short-term sensor location biases tend to even out due to a more uniform wind direction distribution on longer time scales. Using information from footprint modeling, average microform emissions could be derived from the ecosystem-scale eddy covariance data which could be compared with the microform-scale closed-chamber measurements. While the methane emission estimates by the two methods agreed reasonably well for lawns and hummocks, the emission measurements at hollows were substantially lower from the closed-chamber measurements than by down-scaling the eddy covariance methane fluxes. In our view, the most probable reasons for these discrepancies are (1.) an underestimation of methane emissions by the chamber technique, particularly at hollows where emission by ebullition can be pronounced, (2.) the considerable uncertainty of the high-resolution surface classification and a high likelihood for overlooking small-sized hollows which act as methane emission hotspots (Becker et al. 2008), and (3.) the difficulty of sufficiently representing the high spatial variability of methane fluxes even within specific microform types by a limited number of chamber measurement plots. An uncertainty analysis revealed that seasonal ecosystem methane emission budgets are considerably less certain when microform-scale measurements are up-scaled using surface classifications compared to direct ecosystem-scale eddy covariance flux measurements.

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