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Spatio-temporal variability of CH4 fluxes and environmental drivers on a modern flood plain of the Siberian Lena River Delta

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In the course of the amplified climate change in the Arctic, methane emissions may considerably increase due to more suitable production conditions comprising enhanced temperatures, greater abundance of moisture and increased availability of the carbon stock to microorganisms. Since methane exhibits a much higher global warming potential than carbon dioxide, a comprehensive understanding of its spatio-temporal dynamics as well as its key controls is of great importance.

We study the carbon turnover with a focus on methane on the modern flood plain of Samoylov Island in the Lena River Delta (72°22’N, 126°28’E) using the eddy covariance technique. The heterogeneous area around the flux tower (footprint) is characterised by annual flooding, a variety of non-cryoturbated permafrost-affected soils with different degrees of organic matter accumulation, a tundra vegetation dominated by shrubs and sedges and a slightly undulating relief forming elevated, well drained areas und wet, partially inundated depressions.

The measurements ran between June 2014 and September 2015 when methane fluxes were determined using a LICOR 7700 open-path CH4 analyser. The main emissions occurred between June and September determined by spring thaw and refreezing in autumn. The highest methane emissions took place in early August reaching up to 0.03 μmol m-2 s-1. Over the season, the mean methane flux amounted to 0.012 μmol m-2 s-1. This average is based on a large variability of methane fluxes which is to be attributed to the complexity of the footprint. The methane sources are unevenly distributed; thus, the capture of methane fluxes is highly dependent on atmospheric conditions such as stratification and wind direction.

Explaining the variability in methane fluxes is based on three modelling approaches: step-wise regression, neural network and deterministic modelling using exponential relationships for flux drivers. For the identification of suitable flux drivers, a comprehensive data set of potential environmental controls has been acquired. Soil temperatures ascertained at 20 cm depth provide best explanatory power to account for the low-frequency portion of the methane flux signal after estimating them for the footprint in between the six measurements spots with a 2D interpolation routine and then determining their relative contribution to the flux through footprint modelling.

Methane sources are known to be wet areas which exhibit a certain vegetation dominated by Cyperaceae (e.g. sedges and cotton grass) on the flood plain of Samoylov. Patches of this vegetation type could be identified through supervised classification of a high-resolution orthophoto; hence, wet areas likely to emit methane were localised and their relative contribution to the flux signal was obtained through footprint modelling. This data provides relevant information on the high-frequency portion of the methane flux signal. Applying knowledge on the distribution of vegetation in the footprint increased the model fit dramatically and led to coefficients of determination in the range of 0.6-0.7 for 30 min fluxes and 0.7-0.8 for daily means depending on the model choice. In the process the neural network ranks before the deterministic model and the step-wise regression yields the lowest model fit.