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Improving understanding of controls on spatial variability in methane fluxes in Arctic tundra

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The Arctic is experiencing rapid climate change relative to the rest of the globe, and this increase in temperature has feedback effects across hydrological and thermal regimes, plant community distribution and carbon stocks within tundra soils. Arctic wetlands account for a significant amount of methane emissions from natural ecosystems to the atmosphere and with further permafrost degradation under a warming climate, these emissions are expected to increase. Methane (CH_4) is an extremely important component of the global carbon cycle with a global warming potential 28.5 times greater than carbon dioxide over a 100 year time scale (IPCC, 2013).

In order to validate carbon cycle models, modelling methane at broader landscape scales is needed. To date direct measurements of methane have been sporadic in time and space which, while capturing some key controls on the spatial heterogeneity, make it difficult to accurately upscale methane emissions to the landscape and regional scales.

This study investigates what is controlling the spatial heterogeneity of methane fluxes across Arctic tundra. We combined over 300 portable chamber observations from 13 micro-topographic positions (with multiple vegetation types) across three locations spanning a 300km latitudinal gradient in Northern Alaska from Barrow to Ivotuk with synchronous measurements of environmental (soil temperature, soil moisture, water table, active layer thaw depth, pH) and vegetation (plant community composition, height, sedge tiller counts) variables to evaluate key controls on methane fluxes. To assess the diurnal variation in CH_4 fluxes, we also performed automated chamber measurements in one study site (Barrow) location. Multiple statistical approaches (regression tree and multiple linear regression) were used to identify key controlling variables and their interactions.

Methane emissions across all sites ranged from -0.08 to 15.3 mg C-CH_4 m^{-2} hr^{-1}. As expected, soil moisture was the main control determining the direction and magnitude of methane flux, with methane emissions occurring in saturated micro-topographic locations and drier sites showing low rates of uptake. An interesting exception was in tussock sedge vegetation, which had a deep water table (approximately 20cm – 40cm below the soil surface) but which emitted methane in comparable quantities to saturated communities late in the growing season. This highlights the importance of plant transport and of understanding temporal variation in fluxes. Automated chamber measurements from peak and late growing season showed minimal diurnal trends in methane fluxes, indicating that short-term chamber measurements are representative of average diurnal CH_4 fluxes.

The breadth of environmental and vegetation variables measured across a wide spatial extent of arctic tundra vegetation communities within this study highlights the overriding controls on methane emissions and will significantly help with upscaling methane emissions from the plot scale to the landscape scale.

Reference: IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO97811074153