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Measurements of CH_4 fluxes and isotopes reveal changing mechanisms of production and consumption across a thaw gradient in an arctic wetland

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Methane emissions from high latitude wetlands are likely to increase as the Arctic warms and permafrost thaws. Biogeochemical processes in northern wetlands, mires and permanently frozen peats and soil are sensitive to global climate change with significant impacts on the global CH_4 budget. We are limited in our process level understanding of the mechanisms driving changes in CH_4 production and consumption dynamics during permafrost thaw. This limits our capacity to predict the magnitude of and the controls on the response under future climate conditions. To address these gaps, we quantified the isotopic composition of carbon gas fluxes ($\delta^{13}C$ of CH_4 and CO_2) at high temporal frequency during the growing season from Stordalen Mire, a high latitude (68° N) wetland in Sweden. This was done to partition net CH_4 emissions into its component parts, methanogenesis (including both acetoclastic, and CO_2-reductive pathways) and methanotrophy and methylotrophy (which consume CH_4 primarily via aerobic metabolism).

We used newly developed quantum cascade laser technology, linked to automated chambers, to quantify stable carbon isotope changes at high frequency. Our measurements spanned a permafrost thaw gradient, from elevated, well-drained palsas underlain by permafrost to intermediate permafrost sites dominated by *Sphagnum* spp. to wet sites with no underlying permafrost, dominated by *Eriophorum angustifolium.* There were large increases in productivity and CH_4 emissions as well as shifts in the CH_4 production pathway across the thaw gradient. The isotopic composition of CH_4 becomes ^{13}C enriched, apparently due to increased acetoclastic CH_4 production. The palsa sites have no detectable CH_4 emissions. Fluxes from the Sphagnum site have an average isotopic composition of -79.5‰ a value indicative of CH_4 production dominated by CO_2 reduction. This is in contrast to the isotopic composition of CH_4 produced in the Eriophorum sites which averaged -66.4‰Ṫaxonomic and metabolic profiling (16S rRNA gene amplicon, metagenomic and metaproteomic sequencing) indicate that increases in CH_4 isotopic composition are associated with shifts in the archaeal community from the CO_2-reducing *Methanobacterium subterraneum* in the intermediate-thaw site to the acetoclastic *Methanosarcinaceae* in the fully thawed site. These results directly link microbial community composition to ecosystem scale changes in the magnitude and isotopic composition of CH_4 emissions during permafrost thaw. This isotopic shift, if it proceeds with permafrost thaw generally, should be detectable in global atmospheric CH_4 observations, providing an integrating tracer of permafrost thaw processes at ecosystem to global scales.