Geophysical Research Abstracts
Vol. 21, EGU2019-17812, 2019
EGU General Assembly 2019

Temperature Dependency of Methanotrophs in Arctic Tundra Soils

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After carbon dioxide (CO_2), atmospheric methane (CH4) is the most relevant greenhouse gas affected by anthropogenic activities globally. Methane is the most abundant organic gas in the atmosphere and has a global warming potential that is ~25 times that of CO_2. Climate warming in the arctic is occurring at an unprecedented rate, close to double that of lower latitudes, potentially increasing mineralization of organic carbon stored in soils and thawing permafrost and possibly enhancing CH4 production by methanogenic activity. On the other hand, there also is indication of enhanced CH4 consumption (methanotrophic activity), in particular drained upland soils that has the potential to offset CH4 production and even lead to soils to be net sinks of atmospheric CH4. Methanogenic and methanotrophic microorganisms are ubiquitous throughout world soils, and both organisms have well-documented correlations of activity with soil temperature and moisture. However, temperature and moisture responses of methanotrophs are poorly constrained in arctic soils, in particular near freezing and thawing temperatures that characterize arctic soils during much of the year.

This study assessed CH4 production and consumption rates, along with the production of CO_2, in laboratory experiments using high-resolution flux chambers in arctic tundra soils between temperatures from -5°C to 5°C. Results show that CO_2 production strongly increased with temperature, with a strong step increases above freezing temperatures. CO_2 production showed a pronounced hysteresis effect whereby production was higher during decreasing temperatures (i.e. during freezing) compared to the same temperatures during thawing of soils. For methane, thawing soils showed some methane production (methanogenesis) upon thawing around the freezing points, possibly owed to anoxic microsites in the soils. Thereafter, soils consistently turned into net CH4 sinks, with higher net uptake during re-freezing of soils compared to the same temperatures upon thawing. Methanotrophy was observed at temperatures as low as -2°C after which fluxes reached near-zero. Both upper and deeper soils (A and B horizons) were predominantly CH4 sinks under oxic condition, and A-Horizon soils showed much larger fluxes, both of CH4 uptake and CO_2 production, compared to B-Horizon soils, by about a factor 10, consistent with higher organic carbon contents. This study shows sensitive thresholds for CO_2 production and CH4 consumption in Arctic soils near freezing temperatures, with pronounced hysteresis effects of fluxes during freezing and thawing processes.