



Effect of soil organic matter composition on unfrozen water content of frozen soils, and their heterotrophic CO₂ production

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Heterotrophic microbial processes and associated production and emission of atmospheric trace gases proceed during the winter months in the frozen soils of high latitude ecosystems. The ability of soil to retain unfrozen water at below-zero temperatures is integral for this activity. The soil organic matter (SOM) is believed to play an important role for the soil liquid water contents in frozen bulk soil, but the specific factors contributing to this control are presently unknown.

Here we evaluate the effect of the organic chemical composition on the amount of unfrozen water and the microbial heterotrophic activity at below zero temperatures in boreal forest soils. To achieve this, we have characterized the chemical composition of SOM in boreal pine and spruce forest soils using solid state CP-MAS (cross polarization magic angle spinning) NMR spectroscopy. We then use acquired data on SOM composition to elucidate to what extent it can explain the observed variation in unfrozen water content and biogenic CO₂ production rates among the soil samples under frozen conditions (-4°C).

We conclude that aromatic carbon, O-aromatic carbon, methoxy/N-alkyl carbon, and alkyl carbon are the major SOM components affecting frozen boreal forest soils' ability to retain unfrozen water and their microbial CO₂ production. Surprisingly, our results reveal that solid carbohydrates have a negative impact on CO₂ production in frozen boreal forest soils. More recalcitrant SOM compounds, mainly aromatic carbon and alkyl carbon, need to be considered to fully understand winter biogeochemical processes and carbon dynamics in frozen soil. In addition, SOM-associated controls on the unfrozen water content differed between samples originating from Pine forests as compared to Spruce dominated forests. Given the strong link between unfrozen water content and SOM mineralization during winter this may represent a previously unrecognized potential feedback mechanism of global climate change, and these differences in soil characteristics induced by vegetation cover will be discussed.