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CO_2 flux measurements in northern peatland soil incubations: Q_{10} climate trends and alternative model representations under freeze-thaw conditions

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Northern peatland soils have the highest organic carbon density among terrestrial ecosystems. They play an important role as a natural long-term atmospheric carbon sink. With rapidly changing climate, however, increasing soil carbon mineralization rates are of special concern, especially during winter or, more broadly, the non-growing season (NGS), when peatlands exhibit net positive ecosystem CO_2 emissions. While direct CO_2 emission measurements during the NGS are hindered by difficult field conditions, laboratory incubation experiments with peat soil samples may provide less expensive yet informative measurements for CO_2 production rates that enable the systematic examination of various controlling factors. In this study, we collected 0-30 cm peat layers from seven peatland sites across northern temperate to boreal/sub-arctic climate in Canada. To perform incubation CO_2 measurements, each peat sample was divided into five subsamples exposed to varying moisture contents, from desiccation to saturation levels. The variable moisture sub-samples were incubated in an environmental chamber with temperature varying from as low as -10ËšC to as high as +35ËšC. We measured CO_2 production rates every 48 h as the samples cycled through imposed temperature trajectories simulating non-growing season conditions, including a freezing event followed by thawing.

We observed different optimum moisture levels for CO_2 production in the fixed 25ËšC incubations. The experimental optimum moisture level trends could be explained by the in-situ water-table depth distributions at the sampling locations. Overall, the temperature-dependent CO_2 production rates followed simple exponential relationships, yielding Q_{10} values. When arranged by site and climate region, the fitted Q_{10} values showed a statistically significant upward trend with decreasing mean temperatures towards higher-latitude sites. However, the Q_{10} model (that is, the Arrhenius rate model) poorly fitted the CO_2 rates under freezing conditions and subsequent thawing. We therefore explored an alternative kinetic model, the Macromolecular Rate Theory (MMRT) model, which was specifically developed for enzyme-catalyzed metabolic processes. Our work may guide improvements of the parametrization of NGS peatland soil carbon dynamics under future climate warming scenarios.