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Permafrost-carbon feedbacks and climate stabilization costs

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Thawing of permafrost in recent years is reported at various locations in the arctic. Studies using a range of climate models show that permafrost thawing due to arctic warming and resulting CO_2 and CH4 emissions provide feedbacks to the global climate system. However, such permafrost-carbon feedbacks have not been accounted for in the calculations of stabilization emissions scenarios of greenhouse gases and related components to cap the global warming below certain levels (e.g. 2°C target). This raises the following two questions: 1) how permafrost-carbon feedbacks influence the pathways of climate stabilizations and 2) how much permafrost-carbon feedbacks generate additional economic costs to stabilize the temperature.

We derive a simple parameterization of permafrost-carbon feedbacks from the results of (Schneider von Deimling et al. 2012) that show the ranges of CO_2 and CH4 emissions due to the thawing of permafrost under the RCP8.5 scenario. Schneider von Deimling et al. (2012) developed a process-based model to estimate CO_2 and CH4 emissions from mineral and peatland soils distributed across 50 latitudinal bands in the arctic and varied a large number of parameters stochastically to estimate uncertainty ranges in the output. In contrast, we limit the number of stochastic parameters to several and tune them to reproduce the stochastic behavior of the model of Schneider von Deimling et al. (2012). This simple parameterization is based on a linear dependence of the permafrost thaw on global temperature changes and relies on a system of linear reservoirs to control CO_2 and CH4 emissions. It can be easily implemented in Simple Climate Models (SCMs).

We implement such a simplified parameterization of permafrost-carbon feedbacks to the Aggregate Carbon Cycle, Atmospheric Chemistry, and Climate model (ACC2) (Tanaka et al. 2007), which comprises a box model of the global carbon cycle, simple parameterizations of the atmospheric chemistry and the radiative forcing, and a land-ocean energy balance model coupled with a heat diffusion model. To compute stabilization emissions scenarios, we couple ACC2 with an economic module consisting of the Marginal Abatement Cost (MAC) functions for CO_2, CH4, and N2O (Johansson 2011; Tanaka et al. 2013). From this setup, we calculate a stabilization emissions scenario by minimizing the total abatement costs for three gases summed over time with assumed discounting such that the temperature is limited below a specified threshold.

Our preliminary results show that permafrost-carbon feedbacks lead to only a marginal difference in the emission pathway to achieve the 2°target. However, when the stabilization target is not stringent, permafrost-carbon feedbacks modify the stabilization emission pathway significantly, resulting in substantially higher costs of mitigation than those without permafrost-carbon feedbacks.

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