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Model improvement and projection of permafrost degradation and greenhouse gas emission

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To date, the treatment of permafrost in earth system models has been simplified due to the prevailing uncertainties in the processes involving frozen ground. In this study, we improved the modeling of permafrost physical processes in a state-of-the-art earth system model (MIROC) by taking into account some of the relevant physical properties of soil such as changes in the thermophysical properties due to freezing (https://doi.org/10.1186/s40645-020-00380-w). As a result, the improved version of the model was able to reproduce a more realistic permafrost distribution at the southern limit of the permafrost area by increasing the freezing of soil moisture in winter. The improved modeling of permafrost processes also had a significant effect on future projections. Using the conventional formulation, the predicted cumulative reduction of the permafrost area by year 2100 was approximately 60% (40–80% range of uncertainty from a multi-model ensemble) in the RCP8.5 scenario, while with the improved formulation, the reduction was approximately 35% (20–50%). Our results indicate that the improved treatment of permafrost processes in global climate models is important to ensuring more reliable future projections.

In addition, the processes of greenhouse gas (GHG) emissions due to permafrost degradation are not considered in many earth-system models. Therefore, we developed a model to diagnose that processes by using the output of earth system models (https://doi.org/10.1186/s40645-020-00366-8). The model called PDGEM (Permafrost Degradation and GHG Emission Model) describes the thawing of the Arctic permafrost including the Yedoma layer due to climate change and the GHG emissions. Our model simulations show that the total GHG emissions from permafrost degradation in the RCP8.5 scenario was estimated to be 31-63 PgC for CO2 and 1261-2821 TgCH4 for CH4 (68th percentile of the perturbed model simulations, corresponding to a global average surface air temperature change of 0.05–0.11 °C), and 14-28 PgC for CO2 and 618-1341 TgCH4 for CH4 (0.03–0.07 °C) in the RCP2.6 scenario. An advantage of PDGEM is that geographical distributions of GHG emissions can be estimated by combining a state-of-the-art land surface model featuring detailed physical processes with a GHG release model using a simple scheme, enabling us to consider a broad range of uncertainty regarding model parameters. In regions with large GHG emissions due to permafrost thawing, it may be possible to

help reduce GHG emissions by taking measures such as restraining land development.