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Uncertainties in the simulation of permafrost response to global warming

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Permafrost is generally believed to be highly sensitive to global warming, and some studies have projected dramatic reductions in permafrost extent by the end of this century. However, few studies have addressed the uncertainties in simulating the response of permafrost to climate change. Conventional permafrost models are based on well-established relations of permafrost occurrence with climatic variables, but often assume that the ground thermal regime is in equilibrium with the atmospheric climate. The land surface schemes of many climate models, on the other hand, use a process-based approach to simulate the dynamics of frozen ground, but ignore some of the key processes that will determine the pace of the permafrost response, in particular the thermodynamics of the deeper soil. Here we attempt to identify and quantify the different sources of uncertainty in the simulation of the permafrost response to climate change. These include model structure, parameter uncertainty, and uncertainty in the climate signal over permafrost regions. To this end, we used two very different modelling approaches: a stochastic equilibrium model that is able to account for the parameter uncertainty in traditional large-scale models of climate-permafrost interactions; and an updated version of the JULES (Joint UK Land Environment Simulator) land surface scheme, that now includes a representation of organic soils and the deeper soil layers. Both models have been driven by probabilistic climate scenarios from the Hadley Centre (HadCM3) perturbed physics ensemble, that allows for an estimation of the probability density function of key climatic parameters over the region. By using this approach we can compare the level of parameter uncertainty in the stochastic permafrost model to uncertainty in the climate model simulations, and we can determine the differences that arise from the divergent modelling approaches. First results indicate that the spread in the climate scenario ensemble is large, particularly over Eastern Siberia, which may result in a wide range in the equilibrium response of the permafrost in Northern Eurasia. This research has been funded by the UK Foreign & Commonwealth Office.