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Modeling excess ice and thermokarst in the Community Land Model

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Recent advances in the Earth System Models put an effort into accurately representing permafrost, thermal and hydrologic properties of organic soil, biogeochemical cycles, and arctic vegetation succession. However, the current representation of permafrost and ground ice is inadequate to predicting changes in geophysical properties and resulting biogeochemical cycles in regards to permafrost thawing. In ice-rich permafrost areas, permafrost thaw can be followed by subsiding of land surface, called thermokarst, due to melting of ice wedges and lenses. Thermokarst and permafrost thaw effects can create large alteration of surface hydrology and ecosystem carbon cycling. When it occurs on a large scale, thermokarst can expose stable old carbon buried in the permafrost zone and change previously known carbon sink permafrost zone to a large carbon source. Therefore, in order to accurately predict the fate of permafrost carbon under future projections of climate warming, adequate representation of permafrost and ground ice as long as the thaw effects need to be included in the Earth System Models. Here, we report an improvement to the Community Land Model (CLM4.0), the land model of Community Earth System Model (CESM), that expanded the model's capacity of capturing permafrost thaw and thermokarst effects on the arctic land surface to improve hydrology and biogeochemistry in the arctic system. We also simulated current and future probabilities of thermokarst development in the arctic region using the model. In order to accurately simulate thermokarst development, we included 'excess ice' as a new parameter and included the excessive amount of ice in the surface soil layers as well as in soil thermal properties and phase change calculations. The model was initialized with estimates of the current excess ice distribution and amount that are based on the International Permafrost Association ground ice information. We calculated variability in land surface microtopography as a proxy of thermokarst development based on the amount of excess ice melting throughout the arctic landscape over time. Introducing excessive amount of ice in permafrost soil layers significantly reduced the timing of active layer thickening over the simulation period of 1850 to 2100. In addition, soil temperature at 1m depth was lower by approximately 3C in the year 2100 for the excess ice simulations compared to control. We expect that our results would enhance the predictions of CO_2 and CH4 release from the permafrost zone.