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Advances and implications of modeling interactions between soil thermal, hydrologic, and ecosystem states in permafrost-affected zones in the Community Land Model

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Thermal, hydrologic, and ecosystem processes are intricately coupled in permafrost-affected environments and are challenging processes to model. We describe a set of improvements to the Community Land Model (CLM4.5), the land model used in the Community Earth System Model, that expand the model's capability to represent cold region hydrological processes and which resolve several critical biases in the model's high latitude ecosystem simulation. The improvements include changes to the parameterization of vertical soil water flow into and through icy/frozen soils, a representation of the active layer water table position, the introduction of a surface water storage pool that permits a prognostic simulation of wetland distribution, and the introduction of a simple river flooding model. Together, these improvements result in a substantial improvement of the hydrologic, thermal, and ecosystem simulation in permafrost-affected zones, yielding more realistic active layer soil moisture levels which supports more realistic vegetation growth, improved river discharge hydrographs of the Arctic rivers. Prognostic wetland distribution enables a more direct and integrated coupling with a methane emissions model that has recently been developed for CLM. We assess the impact of the more realistic hydrologic simulation on simulations of soil thermal (e.g., active layer thickness and deep ground temperature) and vegetation states. Additionally, we examine how the improved hydrology alters projected permafrost degradation rates.