Geophysical Research Abstracts
Vol. 20, EGU2018-9625, 2018
EGU General Assembly 2018

Towards representing small-scale changes in permafrost hydrology in Earth System Models

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Field observations from a range of permafrost landscapes convincingly show that melting of ground ice can lead to modifications of the drainage regime so that soil moisture conditions can radically change in short time. This not only leads to significant changes in the carbon turnover, but can also trigger further permafrost thaw through complicated feedback loops. Representation of small-scale interactions between hydrology and ground thermal state are a crucial prerequisite for credible projections on a future permafrost carbon feedback. However, the present generation of Earth System Models, based on single column ground models representing coarse grid cells, can not account for such processes, although spatial heterogeneity is to a certain extent represented by means of tiling.

Aiming for structural changes to overcome these challenges, we present the concept of “interacting tiles” developed in the Permanor, COUP and PermaRisk projects: by coupling tiles through lateral fluxes of heat, water and snow, it becomes possible to explicitly represent changes of microtopography, drainage regime and soil water contents triggered by melting ground ice. Simulations with the CryoGrid permafrost model and the Noah-MP land surface scheme suggest that “interacting tiles” is capable of representing a range of thaw phenomena in strongly different permafrost landscapes, ranging from lateral erosion of peat plateaus (sporadic permafrost) to formation of thermokarst ponds and ice-wedge degradation in polygonal tundra (continuous permafrost).

Using field observations from permafrost landscapes, we discuss prospects and challenges for application in coupled circulation models, focusing on model architecture and possibilities for model calibration/validation with field and remote sensing data sets.