Modelling of near-surface permafrost and hydrological processes across different scales and landscapes

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Studying permafrost is impossible without accounting for highly variable in space and time water fluxes. Permafrost hydrology calls for specific limitations and requirements to modelling approaches in comparison to those which are used in traditional permafrost studies. They are related to different temporal and spatial scales which are typically used in hydrology. Soil heat dynamic process simulation for hydrological modelling should, on one hand, take into account the specific features of active layer formation at different landscapes on relatively short time steps (days/hours) and significantly large areas. On the other hand, developed methods must compromise between minimum resort to calibration of model parameters and the use of limited data which is largely unavailable in cold regions.

The goal of presented research is the development of multi-scale approach to simulate near-surface permafrost and hydrological processes which can be applicable at scales from a soil column to large river basins. The proposed approach consists of process-based hydrological Hydrograph model and robust parameterization scheme developed on the basis of historical observations in different landscapes of Eastern Siberia.

The Hydrograph model describes not only all essential processes of land hydrological cycle but also explicitly accounts for soil heat dynamics and water phase changes. Main model parameters refer to observable soil and vegetation properties. It brings the advantage to the Hydrograph model in comparison to parameters calibration approach.

Observational data and related soil and vegetation information collected at the Kolyma and Bomnak research sites representing continuous and discontinuous permafrost environments were used to develop and verify the parameter sets for typical (representative) permafrost landscapes. The approach was tested against point observations of soil thaw/freeze in bare rocks, mountain tundra, sparse larch forest, wet larch forest, birch forest and bogs. Adjusted soil and vegetation parameters were applied without change to simulate runoff formation mechanisms in slope scale homogeneous watersheds (area < 1 km2) and then transferred to the larger basins with area up to 10000 km2 in similar conditions.

We can conclude that near-surface permafrost and hydrological processes are closely related to the observable landscape properties. Explicit implementation of this relation into models through the set of physical parameters could be a proper basis of simulation of ground thaw and runoff generation across different scales.