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PERMAFROST AND HYDROLOGICAL RESPONSE TO THE OBSERVED AND POTENTIAL CLIMATE CHANGE IN THE RUSSIAN ARCTIC DISCONTINUOUS PERMAFROST ZONE

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Hydrological processes and permafrost properties are highly sensitive to the climate variability on the southern limit of permafrost. A minor shift in climate conditions can lead to the permafrost degradation and significant change in the hydrological regime of soils and rivers. The goal of our research was the assessment of changes in permafrost properties (active layer depth, permafrost distribution) and hydrological regime of a small-scale river catchment in the Russian Arctic driven by observed and potential climate variability using coupled process-based hydrological model Hydrograph and stochastic weather generator.

The studied Graviyka River watershed (323 km²) is situated 120 km above the Arctic Circle, in the vicinity of the town of Igarka, in northern part of the Krasnoyarsk Krai, Russia. Although the climate is severe with mean annual temperature -7.9 °C (1936-2013) the Graviyka River watershed is underlain by discontinuous permafrost. Major landscape units within the watershed are mixed forests and elevated frozen peatlands (palsas).

Distributed process-based hydrological model Hydrograph was employed to assess complex interactions between climate, landscape properties, seasonal ground frost dynamics and runoff generation. The model algorithms describe all major processes of land hydrological cycle and ground thaw/freeze including soil water phase change. Initially the Hydrograph model was implemented for the historical period of 1958 to 2013. Model parameters were verified using active layer depth measurements from CALM R40 site for 2008-2013, soil temperature and snow observations conducted by Igarka Geocryological Laboratory in 2011-2013 and the Graviyka River discharge data for 1958-1992. Subsequently, two future climate scenarios were developed for 2015-2060 period, projecting modest and severe shift in climate conditions. Stochastic weather model was used to generate series of meteorological data that served as a forcing for the verified Hydrograph model.

Both observations and modelling results show that the organic layer thickness and soil drainage conditions affect permafrost distribution in the Graviyka River watershed. Process-based modelling indicates that the active layer depth and permafrost distribution strongly affect water distribution between surface, subsurface and groundwater flow. According to the scenario-based modelling results, substantial deepening of the active layer and permafrost degradation along with the decrease in peak floods are the most probable consequences of air temperature increase in the future. Process-based modelling of runoff generation and ground freeze/thaw can serve as a suitable basis for the evaluation of hydrological processes in changing permafrost environment for both past and future time periods.