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Dominant hydrological processes at three contrasting small permafrost watersheds in changing climate

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The most pronounced climatic changes are observed and projected in the Arctic. Large part of the Arctic is influenced by permanently or seasonally frozen ground that controls river runoff generation. The research aims at assessment of observed and projected changes of hydrological regime and identification of dominant hydrological processes at three small watersheds in different landscape and permafrost conditions of Siberia for the last sixty years by data analysis and process-based modelling.

Three studied watersheds are located within the Yenisei, Lena and Kolyma river basins. The Graviyka river basin (323 km2) is situated in discontinuous permafrost in transition zone between tundra and taiga ecotones in the lower Yenisei region. Mean annual precipitation is 510 mm/year and air temperature is -8°C (1936-2014). Both air temperature and precipitation have shown significant increase for the last forty years.

The Shestakovka river basin (170 km2), a tributary of the Lena river near Yakutsk, is characterized by extremely dry (240 mm/year) and cold (-9.5°C) climate of Central Yakutiya. Larch and pine forests grow on sandy deposits covered by continuous permafrost. Air temperature and river flow have increased for the last thirty years but precipitation have shown no significant changes.

The Kontaktovy creek watershed (22 km2) is located in mountains of upper Kolyma river basin. The permafrost is continuous. Main land cover types are bare rocks, mountain tundra and sparse larch forest. Only insignificant changes of air temperature, precipitation and river flow were detected for the last decades.

To assess dominant hydrological processes and to project their future changes in each studied watershed the process-based Hydrograph model was applied to historical and future time periods using temperate and extreme climate scenarios. The Hydrograph model does not rely on calibration and the parameters were estimated using all available a-priori information – thematic maps and descriptions of soil and vegetation. Adjusted parameters were tested against data of active layer depths and water balance studies. Tested set of parameters is considered to be representative for the landscape units and applicable for modelling for the past and future. It was shown that the Hydrograph model is able to reproduce observing trend of annual and maximum flow at different climates and landscapes.

Substantial deepening of the active layer, decrease in peak floods and increase of evapotranspiration are the most probable consequences of air temperature increase for the Graviyka river basin. Decrease of spring flood and increase of minimum flow is projected at the Shestakovka river basin in future due to warming climate. Process-based modelling of runoff generation and ground freeze/thaw can serve as a suitable basis for the evaluation of hydrological processes in changing various permafrost environment for both past and future periods.

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