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Changing river ice and frozen ground in Eastern Siberia: present state and future scenarios

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Large part of Eastern Siberia is covered by permafrost and is accessible only by rivers in summer and ice roads in winter. They critically depend on ice formation dates and thickness. Ground thawing, subsidence, thermokarst and other hazardous cryogenic processes could lead to failure of infrastructure. The study aimed at assessment of current and future climate-induced changes of river ice and active layer depth in Central Yakutia. Hydrological models Hydrograph and HYPE were employed to simulate active layer depth and river ice respectivelywith ensembles of bias-corrected CMIP5 climate model outputs (1971-2100) as forcing representing the emission scenarios RCP4.5 and RCP8.5.

Air temperature in Yakutsk has increased from -10.4 °C (1951-1978) to -8.7 °C (1979-2012). It is expected to further increase by 3.5°C and 6.6°C according to RCP4.5 and RCP8.5 by the end of XXI century. The mean ice thickness of the Lena River at Yakutsk in March and April has decreased in March and April during the period 1955-2015 by 20-35%. River breakup is shifting to earlier dates at a rate of 1.2 days per decade (1939-2015). Ground temperature and thawing depth are relatively stable for the period 1982-2012.

Hydrograph model was applied in a lumped way to simulate active layer depth. The dominant landscapes in Central Yakutia are larch forest with sandy soil, pine forest with sandy soil, larch forest with loamy soil, alas depressions covered by grassland with loamy soil, inter-alas areas covered by larch and birch forests, and marsh. Model parameters were estimated based on field data that is representative for above-mentioned landscapes. Validated on the historical observations Hydrograph model was used for future projection. According to RCP4.5 practically no changes of active layer depth are expected in alas and interalas areas. Deepening of active layer in marshes, pine and larch forests with sandy soils for period 2071-2100 would reach 47-66 cm comparative to 2011-2040. According to extreme RCP8.5 scenario permafrost would completely thaw in upper 5 m in three landscapes with sandy soils while thawing depth would increase only by 15-27 cm in other three landscapes with loamy soils. Simulation results suggest relatively high resilience of alas, interalas areas and larch forests with loamy soils to future warming.

The Arctic-HYPE model was applied to simulate ice depths and freeze-up and break-up dates at river ice road crossings in the Lena, Aldan and Viluy rivers. Local observations from the Lena river at Tabaga, Yakutsk and Khangalassy were used for critical model improvements. Projections towards the end of XXI century under RCP4.5 and RCP8.5 suggests that the ice cover period is likely to be one month shorter than today, both through earlier break-up and later ice formation dates, and reduction of annual maximum ice depth would be in the range 40 to 70 cm.