Changing River Dynamics Cause Permafrost Thaw: exploration from the coupling of a river temperature and a permafrost model

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Degradation of ice-rich permafrost is caused by rapid Arctic warming. Likely this degradation already has altered the water balance by increasing runoff and flooding. But here we ask, how do the hydrological changes in river systems, in turn, affect the permafrost conditions? How does river flooding affects permafrost thermal state in floodplains and deltas? What if the timing of river flooding changes with Arctic warming?
We develop a first-order heat budget approach to simulate evolving river flood water temperature over the seasonal inundation period. Solar radiation, air temperature and wind control the different components of heat exchange between the atmosphere and the river water surface. An additional term specifically calculates the exchange of heat between the river water and the channel bed and subsurface. Then, this river and flood water temperature is coupled to the Control Volume Permafrost Model (CVPM), which models detailed thermal state of shallow permafrost. We apply the combined model to the Kuparuk river floodplain and delta, a medium-sized river system on the North Slope of Alaska. Results indicate that permafrost underlaying the floodplain warms during inundation, and the active layer thickness (ALT) can increase for more several meters with sustained standing water. Permafrost underlying the floodplain farthest laterally from the main channel is only warmed by the short-lived spring snowmelt flood. We find that earlier arrival of the spring freshet and associated earlier inundation onset, as well as the increase of river discharge can significantly increase subsurface permafrost temperature, and lead to the deepening of the activelayer. The sedimentary characteristics of the deposits in the floodplain are an important control on the response of permafrost thermal state to inundation. River corridors, especially in the continuous zone of permafrost in the Arctic, are increasingly vulnerable to future changes in timing and magnitude of freshwater flooding as a result of earlier spring snowmelt and river breakup, and increasing river discharge. I will discuss these results in the more regional context of the National Alaskan Wildlife Refuge river basins – and show how our simulations of the permafrost state predict rapid active layer deepening.

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