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Modeling recent permafrost thaw and associated hydrological changes in an endorheic Tibetan watershed

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Permafrost has a crucial influence on sub-surface water flow and thus on the hydrology of catchments. Its thawing drives the release of frozen water and a transition from surface-water-dominated systems to groundwater-dominated systems. In the context of global warming, these hydrological modifications are of critical importance for extensive headwater regions such as the Qinghai-Tibet Plateau (QTP) and the Himalayas. Permafrost covers a significant proportion of these regions (40% of the QTP), which are major water towers of the world. Therefore, improving our understanding and ability to quantify these changes are a key scientific challenge.

Many watersheds of the QTP have seen their hydrologic budget modified over the last decades as evidenced by strong lake level variations observed in endorheic basins. Yet, the possible contribution of permafrost thaw to these variations has not been assessed. The Paiku basin (central Himalayas, southern TP) finds itself in a similar situation. The Paiku lake at the lowest point of this endorheic basin has exhibited important level decreases since the 70's and thus offers the possibility to test the potential role of permafrost thaw on these hydrologic changes. We present permafrost simulations at the scale of the basin over the last four decades that reproduce its degradation as result of regional climatic change. We use the Cryogrid model to simulate the surface energy balance, snow pack dynamics and the ground thermal regime while accounting for the phase changes and the soil water budget. Because the surface radiative, sensitive and latent heat fluxes in alpine environments are strongly dependent on the physiography the model is forced with distributed downscaled forcing data produced with the TOPOSCALE model to account for this spatial variability. Simulated surface conditions are evaluated against meteorological data acquired within the basin and remotely sensed surface temperatures.

The simulations show that, contrary to large scale estimates of permafrost occurrence probability, an important part of the basin is underlaid by permafrost. During the simulated period, permafrost distribution and active layer exhibit limited variations (active layer deepening neighboring 10 cm) yet deeper ground temperatures (7-8 m) show a warming close to 0.8 degree

(0.2 degree per decade). These first results tend to indicate a limited contribution of permafrost to the catchment hydrology over the last decades, a trend that could be significantly modified in the future if the simulated warming rates persist and lead to increased permafrost thawing.