Pan-arctic ice wedge degradation in continuous permafrost and hydrological implications

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Wetlands underlain by ice wedge polygons occupy a significant portion of Arctic terrestrial landscapes. The different types of ice wedge polygons, i.e. low- and high-centered, with and without well-developed troughs and pits, can cause major differences in the hydrologic cycle that ultimately impacts habitat availability, connectivity and quality of aquatic ecosystems. By using a collection of satellite imagery, ground and aerial photos, we present observations of recent historical ice wedge degradation at multiple locations within the continuous permafrost zones of North America and Eurasia. The subsequent ground subsidence, which is documented at places to have occurred within a10 yr time period or less, has resulted in major surface water alterations leading to increasing moisture contrasts across the landscape. Informed by the satellite, aerial and in-situ image observations, our hydrologic model experiments explore the impacts of polygon, and specifically trough-type, on watershed-scale water balance components with a focus on the extent and duration of surface water availability and connectivity. The hydrologic model, WaSiM, includes 1D soil heat transfer via conduction and advection linked to the mass balance modules, which include but are not limited to overland flow, ponding, moss and open water evaporation, evapotranspiration, 2D saturated (groundwater) and 1D unsaturated domains. Aimed at simplifying the landscape, the scenarios suggest the importance of troughs characteristics in laterally connecting landscape-scale hydrology, controlling heterogeneous distribution of snow and therefore, impacting surface water extent and duration. We propose that not accounting for the ice wedge polygon topography, including ground subsidence or the lack thereof, undermines the effectiveness of any short- (<10 yr) to long-term (>10 yr) projections of local to regional hydrology in the majority of Arctic permafrost lowlands.

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