High-Resolution Mapping of Ice Wedge Polygons for Environmental Applications

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It is well known that microtopography associated with ice wedge polygons drives pronounced, meter-scale spatial gradients in hydrologic and ecological processes on the tundra. However, high-resolution maps of polygonal geomorphology are rare, due to the complexity and subtlety of ice wedge polygon relief at landscape scales. Here we present a novel method to rapidly delineate and measure the microtopography associated with individual ice wedge polygons within high-resolution digital elevation models (DEMs). At its core, the method relies on a convolutional neural network paired with a set of common image processing operations to segment a DEM into discrete polygons. The relief at the center relative to the periphery of each polygon is then calculated, placing each instance on a spectrum between low-centered and high- centered endmembers. The robustness of the method is demonstrated through application across a ~1,200 km^2 landscape south of Prudhoe Bay, capturing $>10^6$ individual polygons. Manual validations suggest that the results at both spatial scales are highly accurate; in general, >90% of polygons extracted by the algorithm are correctly delineated. The resulting maps permit visualization of heterogeneity in ice wedge polygon geomorphology with unprecedented detail, revealing complex patterns in the spatial distribution of low-centered and high-centered polygons across diverse landforms. We demonstrate one application of the map, by using it to parameterize a simple analytical model of groundwater flushing from the active layer of ice wedge polygons. The results place an upper bound on the landscape-scale flux of water from polygonal soils into thermokarst troughs, which may represent an important pathway for mobilization of dissolved organic carbon and other nutrients.