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Projecting future permafrost thaw and subsidence driven infrastructure damage in the discontinuous permafrost zone

Louise Farquharson[1], Dmitry Nicolsky[1], Monika Calif[2], Jennifer Schmidt[3], Vladimir Romanovsky[1], and Thomas Douglas[4]

[1]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, USA (lmfarquharson@alaska.edu)
[2]SOKA University, Aliso Viejo, USA (mcalef@soka.edu)
[3]Institute of Social and Economic Research, University of Alaska Anchorage, Anchorage, USA (jischmidt@alaska.edu)
[4]US Army Cold Regions Research and Engineering Laboratory Fort Wainwright, Fairbanks, USA (thomas@thomasdouglas.com)

Permafrost thaw, ground-ice melt, and associated ground settlement pose significant hazards to northern communities and industry. Thaw of permafrost affected soils can decrease bearing capacity while settlement due to ground ice melt can cause ground collapse (thermokarst) and localized flooding. Here, explore ground ice distribution and potential for thaw induced settlement in the Fairbanks North Star Borough (FNSB), located in an area of discontinuous permafrost in Interior Alaska, USA. Pleistocene-Holocene sediment deposition, ice wedge development, and subsequent reworking due to thaw and hillslope processes have left a complex mosaic of cryolithological conditions that make thaw-related hazards a challenge to predict. The Borough is home to critical infrastructure including two military bases, a university, several gold mines, and the Trans Alaska Pipeline.

We created a permafrost hazard map by combining modelled ground ice distribution with projections of ground temperature through to 2090 using the GIPL 2.0 model for key ecotypes in the area. From this we were able to infer temperature dynamics, active layer deepening, talik development, and the potential for thermokarst degradation for IPCC Representative Concentration Pathway scenarios 4.5 and 8.5 through to 2090. We established ground ice distribution through a combination of existing geologic maps, numerical modeling, lidar derived thaw feature maps, and industry bore holes. To extrapolate ground ice values from the representative sub-sample of ~ 2000km^2 to the entire Borough we utilized a gradient-boosted decision tree aggregate model.

Across the FNSB 23 % of the terrain is underlain by the high ground ice class, 10% medium, 4% low, 44% negligible, and 17% of the region is unaffected. High ground ice content underlines 23 % powerlines, 21% of roads and 4% of critical infrastructure (schools, hospitals, power plants etc.).

Future projections of subsidence in areas of black spruce forest under RCP4.5 and 8.5 for areas respectively show that areas of high ice content could see subsidence of up to 5 and 10 meters respectively by 2090. Subsidence values for a range of topographic locations were calculated. Results from this study may help the FNSB, land managers, and homeowners best prepare and plan for the impacts of climate change in the Fairbanks region and potentially provide a hazard mitigation and climate change adaptation guides for other sub-Arctic communities.