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Identifying vegetation-geomorphology relationships in permafrost with airborne LiDAR, electrical resistivity tomography, seasonal thaw depth measurements, and machine learning

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Mean annual temperatures in interior Alaska, currently -1°C, are projected to increase as much as 5°C by 2100. An increase in mean annual temperatures is expected to degrade permafrost and alter hydrogeology, soils, vegetation, and microbial communities. Ice and carbon rich “yedoma type” permafrost in the area is ecosystem protected against thaw by a cover of thick organic soils and mosses. As such, interactions between vegetation, permafrost ice content, the snow pack, and the soil thermal regime are critical in maintaining permafrost. We studied how and where vegetation and soil surface characteristics can be used to identify subsurface permafrost composition. Of particular interest were potential relationships between permafrost ice content, the soil thermal regime, and vegetation cover. We worked along 400-500 m transects at sites that represent the variety of ecotypes common in interior Alaska. Airborne LiDAR imagery was collected from May 9-11, 2014 with a spatial resolution of 0.25 m. During the winters from 2013-2019 snow pack depths have been made at roughly 1 m intervals along site transects using a snow depth datalogger coupled with a GPS. In late summer from 2013-2019 maximum seasonal thaw depths have been measured at 4 m intervals along each transect. Electrical resistivity tomography measurements were collected across the site transects. A variety of machine learning geospatial analysis approaches were also used to identify relationships between ecosystem characteristics, seasonal thaw, and permafrost soil and ice composition. Wintertime measurements show a clear relationship between vegetation cover and snow depth. Interception (and shallow snow) was evident in the birch and white spruce forests and where dense shrubs are present while the open tussock and intermittent shrub regions yield the greatest snow depths. Results from repeat seasonal thaw depth measurements also show a strong relationship with vegetation where mixed birch and spruce forest is associated with the deepest seasonal thaw. The tussock/shrub and spruce forest zones consistently exhibited the shallowest seasonal thaw. Roughly 60% of the seasonal thaw along the transects occurred by mid-July and downward movement of the thaw front had mostly ceased by late August with little additional thaw between August 20 and early October. Summer precipitation shows a relationship with seasonal thaw depth with the wettest summers associated with the deepest thaw. Results from this study identify

clear relationships between ecotype, permafrost composition, and seasonal thaw dynamics that can help identify how and where permafrost degradation can be expected in a warmer future arctic.