Geophysical monitoring of hydrological dynamics in a transitional permafrost system

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Increasing temperatures in the Arctic are rapidly changing the Arctic ecosystem. Yet, we are missing a predictive understanding of the interactions within the bedrock to atmosphere column that are driving ecosystem evolution and carbon-climate feedback. A critical knowledge gap within these systems are the dynamics of surface water - groundwater interactions, and infiltration and groundwater flow processes, which drive permafrost thaw and biogeochemical processes. Geophysical techniques have been shown to be a valuable tool to assess the intermediate depths (1 - 10's of m) that are particularly important to understanding the impact of climate change on permafrost thaw dynamics and related hydrological dynamics. In this study we assess the variability of hydrological properties and processes in transitional permafrost environments, and the impact of vegetation and snow-pack distribution on those properties.

As part of the Next Generation Ecosystem Experiments (NGEE) Arctic project, we present data from a 127 meter long electrical resistivity tomography monitoring transect located on the Seward peninsula, Alaska, USA, that spans across different vegetation types, snowpack thicknesses and permafrost table depths. The system has been recording data daily between March and November of 2018 and 2019. Here, we focus on the subsurface response of disturbances due to snowmelt and extreme rainfall, and the long-term changes in resistivity. The results highlight considerable variability along the monitoring transect. Areas covered by tall shrubs are characterized by increased snow accumulation, which insulates the ground from cold air temperatures and allows for rapid infiltration of snowmelt. Low-lying graminoid dominated areas have thinner snowpack, resulting in near-surface permafrost and surficial freezing. This lowers the hydraulic conductivity of the shallow subsurface and prevents snowmelt and rainfall from infiltrating into the subsurface. The results highlight the heterogeneity in thermal and hydrological fluxes in transitional landscapes, with increased fluxes in unfrozen areas and presence of lateral flow between the domains that could be a driving factor in talik formation. Calibrated long-term resistivity changes indicate that permafrost temperatures increased by about 0.20°C over the two year monitoring period. This rate is in agreement with independent temperature measurements and general trends observed in similar environments. Our results show that topography, vegetation and snow thickness are main drivers for talik development, and that hydrological properties change significantly with warming permafrost temperatures. These results will eventually help to improve predictions of Arctic feedback to climate changes.