Quantifying the Influence of Bedrock, Soil, Snowpack, Topography and Vegetation Properties on Subsurface Thermal Regimes across an Arctic Watershed in a Discontinuous Permafrost Environment

Baptiste Dafflon[1]*, Sebastian Uhlemann[1], Ian Shirley[1], Patrick McClure[1], Stijn Wielandt[1], Carlotta Brunetti[1], John Peterson[1], Craig Ulrich[1], and Susan Hubbard[1]

[1]Lawrence Berkeley National Laboratory, Berkeley, CA Contact: (bdafflon@lbl.gov)
Project Lead Principle Investigator (PI): Stan Wullschleger BER Program: TES
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In Arctic regions, quantifying the soil and bedrock properties, their thermal-hydrological behavior and their links with landscape properties is particularly challenging yet critical for predicting the storage and flux of carbon and water in a changing climate. This study aims at improving the quantification of subsurface properties and thermo-hydrological fluxes, and their interactions with ground surface and vegetation properties in discontinuous permafrost environments. Our work takes place in a watershed along Teller road near Nome (Alaska) and is part of the Next-Generation Ecosystem Experiments (NGEE-Arctic). The watershed shows significant heterogeneity in vegetation, snowpack, geomorphic and subsurface characteristics.
We use a variety of aerial and ground-based measurements, including electrical imaging, seismic refraction, geophysical well logging, a Distributed Temperature Profiling (DTP) system, CO_2 efflux and water content measurements, soil sample analysis, and UAV-based mapping of snow thickness and vegetation characteristics. Data analysis is performed following an ecosystem-type construct to identify how areas with distinct distribution of above- and belowground properties can be delineated using remote sensing products and a limited amount of ground-based measurements. The data analysis is supported by numerical approaches that simulate hydrological, thermal and biogeochemical processes. Overall, this study enables the identification of watershed structure and associated subsurface and landscape properties. Our unique dataset has highlighted significant relationships between above- and belowground characteristics including: (1) the effects of topographic lows and tall shrubs on thick snowpack and talik distribution; (2) the significant spatial co-variability between permafrost characteristics, soil properties, vegetation, and geomorphology, with graminoid covered areas corresponding to zones having the shallowest permafrost table; (3) the rapid soil thermal-hydrological responses to snowmelt and intense rainfall events, and the increasing permafrost thaw following thick snowpack year, as imaged by automated monitoring of electrical resistivity, temperature and moisture; and (4) the significant influence of soil hydrological and thermal behavior on soil CO_2 efflux. Further, numerical models with adequate parameterization and level of process representation improve our understanding of how near-surface permafrost transitions to talik and absence of permafrost. The obtained information is expected to be useful for improving predictions of Arctic ecosystem feedbacks to climate.