Permafrost Vulnerability Framework from Multiple Essential Climate Variables

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Permafrost is a key indicator of global climate change and hence considered an Essential Climate Variable (ECV). Current studies show a warming trend of permafrost globally, which induces widespread permafrost thaw, leading to near-surface permafrost loss at local to regional scales, impacting ecosystems, hydrological systems, greenhouse gas emissions, and infrastructure stability. Permafrost is defined as the thermal state of the subsurface but is greatly influenced by changes in the surface energy budget, as it is tightly connected to the atmosphere, biosphere, geosphere, and cryosphere by topography, water, snow, and vegetation. However, so far, a combined assessment of these components to better understand, quantify, and project permafrost thaw is still missing.

Therefore, the objective of this ongoing project is to develop a permafrost vulnerability framework which focuses on changes in the surface energy budget and identifies permafrost areas that are particularly vulnerable to thaw by assessing positive and negative feedbacks and interactions in this coupled system. We will derive feedbacks impacting the thermal state of permafrost from spatiotemporal variability assessments of relevant ECVs, including land surface temperature, land cover, snow cover, fire, albedo, soil moisture, and freeze/thaw state. These ECV data sets are derived from remote sensing products. By conducting spatiotemporal variability analyses of the individual ECV parameters, correlation assessments, and decadal trend analyses, a better understanding of the underlying dynamics will be established. Two modelled permafrost ECV products, ground temperature and active layer thickness, serve as spatially continuous observation respondents regarding remotely sensed ECV records. A full range assessment of remotely sensed ECVs will be performed based on permafrost in-situ records.

These results will be input for a circumpolar Arctic permafrost vulnerability assessment. The anticipated output will be a more comprehensive and spatially detail-rich understanding of permafrost vulnerabilities, which in turn is useful for quantifying the permafrost-climate feedback.

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Mapping Ice-Rich Permafrost Using Insar Observations of Late-Season Subsidence

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Ground ice is foundational to the integrity of Arctic ecosystems and infrastructure. However, we lack fine-scale ground ice maps across almost the entire Arctic, chiefly because there is no established method for mapping ice-rich permafrost from space. Here we assess whether remotely sensed late-season subsidence can be used to identify where the upper permafrost is rich in ground ice. The idea is that, towards the end of an exceptionally warm summer, the thaw front can penetrate materials that were previously perennially frozen, triggering increased subsidence if they are ice rich.

Focusing on northwestern Alaska, we test the idea by comparing the Sentinel-1 InSAR late-season subsidence observations to permafrost cores and an independently derived ground ice classification. We find that the late-season subsidence in an exceptionally warm summer was 4–8 cm (5th–95th percentile) in the ice-rich areas, while it was low in ice-poor areas (-1–2 cm; 5th–95th percentile). The distributions of the late-season subsidence overlapped by 2%, demonstrating high sensitivity and specificity for detecting ice-rich upper permafrost. The strengths of late-season subsidence include the ease of automation and its applicability to areas that lack conspicuous manifestations of ground ice, as often occurs on hillslopes. One limitation is that it is not sensitive to excess ground ice below the thaw front and thus the total ice content.

Late-season subsidence can enhance the automated mapping of permafrost ground ice on large scales. It is com-