Thawtrendr: Characterizing patterns of disturbance history in permafrost landscapes using Landsat time-series segmentation algorithms

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Landscapes across the Circumpolar North are undergoing rapid, widespread and unprecedented change in recent decades due to thawing permafrost associated with climate warming. This has globally important consequences for the social-ecological systems supported by these landscapes, including wildlife habitat and subsistence resources, infrastructure and transportation, hydrology and energy balance, and carbon-climate feedbacks. However, we lack a consistent and comprehensive source of information for landscape change across large, remote and inaccessible permafrost regions. Recognizing the vulnerability of these ecosystems to change, scientists and decision-makers have identified a critical need for research that employs remote sensing technologies and methodologies to observe, monitor and understand changes in Arctic and Boreal ecosystems. The availability of long-term, historical records of remote sensing imagery – and the maturation of algorithms and computing resources to extract information from them – offer new capabilities for characterizing thaw-related landscape change at high resolution and continental-scale coverage. Here, we demonstrate a proof-of-concept of the *Thawtrendr* approach that leverages existing Landsat-based, time-series segmentation algorithms tailored to detecting and attributing the key indicators of permafrost landscape dynamics, including changes in vegetation composition, landscape wetting and drying, wildfire, and thermokarst processes.

The core concept of the approach presented here is based on the idea that current landscape conditions with respect to ecosystem composition, structure and function are an outcome of their past disturbance history. This concept has been demonstrated in studies that used disturbance history metrics calculated from time-series of Landsat vegetation indices to predict biomass in temperate forests. We contend that these algorithms can be extended to permafrost regions, and tailored to detect vegetation disturbance and recovery trajectories over time in arctic tundra and boreal forest ecosystems. Here, we describe the *Thawtrendr* approach that

1. calculates landscape change metrics generated by a time-series segmentation algorithm working on temporally-dense image stacks from the Landsat archive (1984 – present), and
2. spectral data indices from current-year Landsat 8 imagery.

To demonstrate this approach, we conducted targeted studies for exiting research areas in Alaska, USA, where known permafrost disturbance agents are driving landscape changes in both tundra and forest ecosystems. The time-series segmentation algorithm was run on the Google Earth Engine to map disturbance history metrics for each of these sites. The disturbance history metrics and the spectral data indices were input to classification algorithms trained on *in situ* and expert interpretation data sets developed at these sites. We show the preliminary results of this approach for its utility in detecting vegetation disturbances and characterizing various thaw-driven landscape change trajectories. Finally, we discuss the potential for this approach to serve as a key tool for scaling the airborne and field-based data being collected from the large-scale ecosystem modeling studies on-going in this region, including NASA's Arctic-Boreal Vulnerability Experiment (ABoVE) and DOE's Next Generation Ecosystem Experiment (NGEE-Arctic).