Detection of recent permafrost region disturbances across the Arctic and Subarctic with Landsat time-series and machine-learning classification

I. Nitze[1], G. Grosse[1,2], B. M. Jones[3], V. E. Romanovsky[4], & J. Boike[1,5]

[1] *Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research*;
[2] *Institute of Earth and Environmental Sciences, University of Potsdam Germany*;
[3] *Water and Environmental Research Center, Institute of Northern Engineering, University of Alaska Fairbanks, Fairbanks, USA*;
[4] *Geophysical Institute, University of Alaska Fairbanks, USA*;
[5] *Geography Department, Humboldt-University Berlin, Berlin, Germany*

Local observations indicate that climate change and shifting disturbance regimes are causing near-surface permafrost degradation in Arctic and Boreal regions. Here, we quantify the abundance and distribution of key permafrost region disturbances (PRDs: lakes and lake dynamics, wildfires, and retrogressive thaw slumps) using dense time series analysis of 30-m resolution Landsat satellite imagery from 1999 to 2014 in conjunction with machine-learning classification, object-based image analysis and auxiliary data sources. Our dataset spans four latitudinal, continental-scale transects in North America (Alaska, Eastern Canada) and Eurasia (Western Siberia, Eastern Siberia), covering ≈10 % of the northern permafrost region.

For the more than 640,000 lakes covering 5.04 % of the study area a net decreasing lake area (-1.45 %) was detected. We observed major lake area decrease in north-western Siberia and parts of western Alaska, while continental eastern Siberia (Central Yakutia) was affected by a significant increase in lake area. The Alaskan and Siberian Transects showed complex spatial dynamics with several influencing factors, such as permafrost extent, geomorphology or climate. The formerly glaciated Eastern Canadian Transect with predominantly bedrock geology exhibited a gradual transition from stable lakes in the south towards increasingly shrinking lakes in the north. Fires were the most extensive PRD across boreal regions (6.62 %), with major abundance in dry continental regions, such as interior Alaska (8.89 %), Eastern Siberia (8.15 %) and boreal Eastern Canada (5.06 %). Western Siberia, with high abundance of wetlands, was less affected by wildfires (2.43 %). Within our study regions, tundra fires were limited to northern and western Alaska (1.07 %).

Active retrogressive thaw slumps, while dramatic on local scales, were spatially restricted to around 5 km^2 within the analyzed region. Due to their small size likely below the detection limit, many RTS may have not been identified safely. However, their clustered occurrence, mainly along former glacial margins (ice-sheets and mountain glaciers) and very ice-rich permafrost in Siberia and Alaska, can help to target their identification with higher spatial resolution data.

Our analysis demonstrates the global-scale vulnerability of permafrost terrain and carbon pools to disturbances and potentially rapid future thaw across very large regions. Our findings highlight that these PRDs need to be included in next generation land surface models to correctly capture the permafrost carbon feedback.