# Repeat terrestrial LiDAR for quantification of extensive thaw subsidence within different tundra vegetation groups

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Permanently frozen ground in the Arctic is being destabilized by continuing permafrost degradation, an indicator of climate change in the northern high latitudes. Increased intensity of ground settlement through ground ice melt caused by rising summer air temperatures result in widespread geomorphological activity. Because these phenomena are hard to detect, they have received not much attention, despite their potentially global significance through the permafrost carbon feedback. The objective of our study is to analyze time series of repeat terrestrial laser scanning (rLiDAR) for quantification of extensive land surface lowering through thaw subsidence, which is the main unknown in terms of recent landscape development in the vast but neglected East Siberian Arctic. Local field measurements (active layer thickness, meteorology, ground temperature, geodetic surveys) during several recent Russian-German Arctic expeditions on Sobo-Sise Island in the eastern Lena Delta and on the Bykovsky Peninsula close to Tiksi help differentiating factors causing relief and land cover changes. Our work aims at finding commonalities and differences of change or no change on yedoma uplands and surrounding slopes, where we expect recent changes to take place first.

First repeat measurements have been made during the Lena Delta expedition in August 2016. We operated the Leica MultiStation MS50, a hybrid instrument combining high-accuracy surveying with fast laser scanning capabilities, from many different positions inside the survey grids. Resulting point clouds have been interpolated to DEM rasters, portraying the land surface in unprecedented detail. Complementing our surveys, we conducted botanical mapping within the extent of our survey grids. This allows us to relate elevation differences to specific surface conditions and enhances our capabilities to extrapolate our local observations to larger areas through land-cover classifications of multispectral remote sensing data such as RapidEye, WorldView-2, and WorldView-3. Additionally, highly detailed digital elevation models (DEMs) with sub-metre accuracy have been stereophotogrammetrically derived from WorldView-1, WorldView-2 and GeoEye satellite data for all study sites. These DEMs are not only an essential prerequisite for the conversion of oblique imagery into ortho-images with the geometry of a map, allowing temporal image stacking for enhanced multispectral classification of tundra vegetation communities, but also contain valuable terrain height information for the evaluation of subsidence-relief interdependencies. When calculated as rates over time, land surface lowering in the ice-rich permafrost regions of northern Siberia amounts to 3-10 cm per year. This local understanding of processes will help to interpret InSAR-based permafrost degradation quantification efforts over large remote polar regions with high temporal earth observation missions such as the Sentinel-1 satellite constellation.