from -1.6 °C (in winter) to -0.8 °C (in summer) at a depth of 4.4 m. The rock temperature is constant (-2.1°C) at a depth of 10 m.

Thus, the permafrost in the Sentsa River Valley is presented by ice-rich lacustrine-alluvial deposits. The mean annual rock temperature is -2.1°C at a depth of 10 m. Frost mounds were formed during sediment freezing. The studied frost mound has a cryogenic formation, a combined segregation-injection genesis as probable. It is evidenced by its structure (interbedded ice lenses and ice-rich silts and clayey silts) as well as the chemical and isotopic composition of ice.

In the recent decade due to increasing average annual air temperatures, an active destruction of frost mounds in the Sentsa River Valley is accompanied by the formation of small and large thermokarst lakes, and by a significant annual retreat of floodplain terraces as a result of thermal erosion.

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REPEAT TERRESTRIAL LIDAR AND DEM-BASED CHANGE DETECTION FOR QUANTIFICATION OF EXTENSIVE THAW SUBSIDENCE ON YEDOMA UPLANDS

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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. Accelerated coastal erosion due to sea ice reduction and an increased intensity of ground settlement through ground ice melt caused by rising summer air temperatures result in widespread geomorpho-logical activity. However, particularly in the light of the enormous area underlain by ice-rich continuous permafrost, still only few observations of permafrost-thaw related landscape dynamics exist. 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. These *in-situ* data provide the basis for calibration and validation of large scale surface change assessments using very high resolution space-borne elevation data with high precision.

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 complement our remote sensing studies and 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. The established subsidence survey grids are equipped with glassfiber benchmarks anchored deep in the permafrost. These benchmarks serve as long-term height reference markers for terrestrial laser scanning. The set-up is generally geared towards a comparison of several measurement campaigns for quantifying modern thermokarst rates not only with high spatial but also high temporal resolution of interannual intervals.

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. The radius of laser scans was usually in the range of 80-100m in order to ensure overlap between neighboring scans and to capture micro-topographical features resulting from permafrost thaw. Accurate positioning of the MS50 is realized using our fixed benchmarks that have been surveyed with precise GNSS instruments. Depending on specific measurement tasks, we operated the MS50 in various scanning modes, optimized either for longer distances, higher precision, or fast scanning. 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 distance and area measurements, but also contain valuable terrain height information for 3D change detection, in case of DEMs representing the state of a study area at different points in time.

A novel approach we are currently evaluating is the comparison of our detailed DEMs with ICESat (Ice, Cloud, and Land Elevation Satellite) space borne laser altimetry data. ICESat provided multi-year elevation data from 2003 to 2009. Dense along-track point spacing of 170 m with high precision and a time lag of more than a decade compared to our modern elevation opens up the possibility to quantify thermokarst rates over large regions and across climatic and topographic gradients. The time span bracketed on the one side by ICESat data beginning from 2003 on the one side and DEMs representing the current 2015/2016 topography captures not only several all-time sea ice minima of the 21st century, but also the warmest summers since records began. The results show that for all study regions elevation differences are almost always negative. 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. We are currently in the stage of expanding these analyses on all key study sites where high resolution DEM data has been made available through the European Research Council funded project PETA-CARB.

DEMs were also used to extrapolate thickness measurements of the protective layer, which covers pure ground ice bodies on an empiric basis. Relating active layer and protective layer thicknesses to our observations of elevation change revealed interesting of patterns thaw subsidence and highlights the vulnerability of ice-rich permafrost to recent environmental changes in the Arctic. This local understanding of processes will help to identify and quantify permafrost degradation over large remote polar regions with future earth observation missions.