Analyzing tundra vegetation characteristics for terrestrial LiDAR surveys of permafrost thaw subsidence

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Surface subsidence is a widespread phenomenon in Arctic lowlands characterized by permafrost deposits. Together with active layer thickness dynamics surface subsidence is an important indicator of permafrost degradation in climate warming conditions. Due to small changes of surface heights of several centimeters or less per year, high-resolution and high-accuracy data are necessary to detect thaw subsidence dynamics in tundra lowlands. An appropriate method to receive such data is repeat terrestrial laser scanning (LiDAR). However, for LiDAR data analysis, uncertainties connected with vegetation dynamics should be taken into account. For example the cotton grass tussocks (*Eriophorum vaginatum*) with large areal coverage of up to 70 – 80 % on Yedoma uplands may exhibit significant interannual variability in leave length and tussock density. Depending on wetness, possible influences might result from moss-lichen cover and its thickness dynamics. The vegetation type and its succession also interacts with the microrelief and is a major endogenous parameter for active layer development, resulting in an areal differentiation of surface heights changes. In this study we present some results of the vegetation characteristics and dynamics in context of its impact on the terrestrial LiDAR investigations for thaw subsidence assessment in an ice-rich permafrost region.

During expeditions to the Lena Delta and the Bykovsky Peninsula in Northern Yakutia in 2015 – 2016, repeat terrestrial laser scanning was conducted on Yedoma uplands consisting of very ice-rich Ice Complex deposits. On the Bykovsky Peninsula, detailed vegetation descriptions of the main vegetation types were done including all species projective cover, cotton grass tussocks height and area sizes, moss-lichen thickness and ALT measurements(Fig. 1).

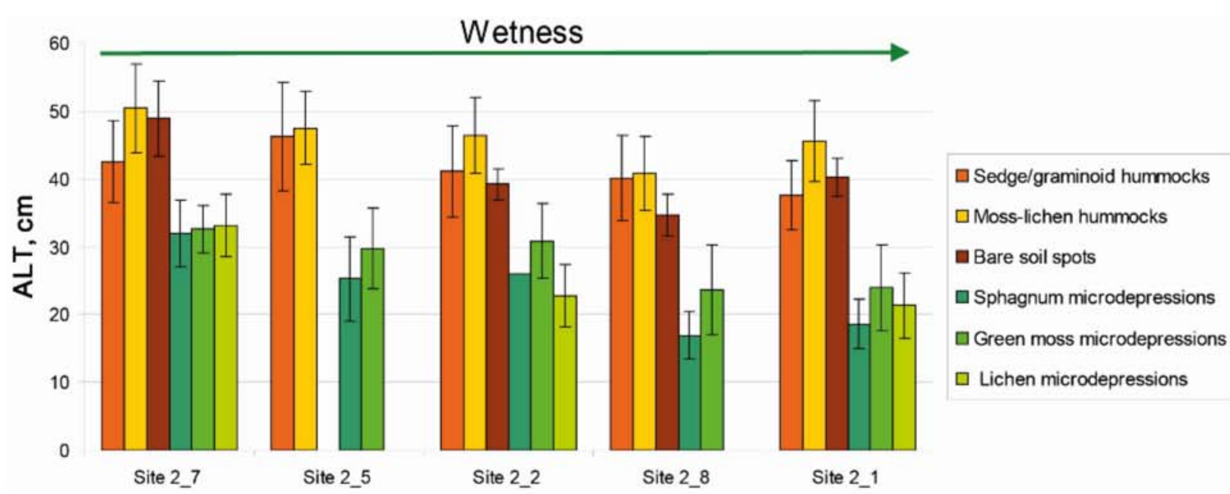

Figure 1: ALT measurements within main vegetation types for different species.

To understand the relationship between the distance, incidence angle, penetration depth and vegetation, a laser scanning experiment was done using a soil and vegetation excavation on a flat desk that was scanned at varying distinct distances.

Subsidence was about 3.5 cm on average and is mostly observed on drained inclined sites with dwarf-shrub graminoid, cotton-grass, moss-lichen tundra, representing initial baydzherakhs (thermokarst mounds). Surface heave is observed mainly within bogged depressions with sedge, moss tundra. The average ALT was 39 $\pm$4.1 cm and 32 $\pm$5.6 cm in 2015 and 2016, respectively. However, the ALT significantly varies locally and depends on the vegetation type and species (Fig. 1).

Cotton grass leaves average length decreased from 14.4 in 2015 to 12.9 as well as tussock area size (0.32 m^2 in 2015, and 0.13 m^2 in 2016). This data can be used for the interpretation of LiDAR data for sites with cotton grass prevalence.

Less deep ALT and cotton grass size in 2016 indicate that climate conditions were less favorable for seasonal subsidence development in 2016. The sum of positive daily air temperatures was almost in the same order of magnitude in 2016 as in 2015 for the period until end of August (636 degree days in 2015 and 628 degree days in 2016). However, interannual surface subsidence was progressing, indicating a decreased resistivity of Yedoma uplands in terms of thaw subsidence under current, generally warmer conditions.

Our results shows the importance of considering vegetation and their dynamics for the interpretation of repeat terrestrial LiDAR data for thaw subsidence estimation.