Decadal scale variation of permafrost active layer thickness at larch forests in eastern Siberia

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To clarify the effects of forest ecosystem components on decadal-scale changes in permafrost active-layer thickness (ALT), we investigated the thermal conditions of the active layer in two larch-dominated forests in the Lena basin. One is the Spasskaya Pad station (SP) on an alluvial terrace near Yakutsk (62° 15´N, 129° 14´E). The other is Elgeeii (EG) station (60° 0´N, 133° 49´E) located at an erosional plain, 300 km southeast of Yakutsk. These two sites have contrastive soil characteristics; sandy-loam soils at SP have less water retention than clay-loam soils at EG. SP has drier soils than EG, reflecting the differences in precipitation, soil texture, and ecosystem water balance. Based on continuous measurement of soil temperature and water and sensitivity analysis using land-surface modeling, we investigated decadal scale variation of ALT and its influence factors.

At SP, the ALT increased from 2005 onwards at a rate of 0.25 m/decade from 1998 to 2019 ($p < 0.01$). According to the breakpoint analysis, ALT at SP increased until 2013 (0.39 m/decade), but after 2013 it decreased again (−0.33 m/decade) (Figure 1). The 2010–2019 average (SD) ALT differed between the sites: it was 1.68 (0.11) m and 1.80 (0.10) m at SP and EG, respectively ($p < 0.01$). However, there was no difference between the two sites with respect to the date of maximum thaw (i.e., data of ALT obtained); the average (standard deviation [SD]) for 2010¬2019 was day 257.7 (6.9) and 256.7 (5.7) at SP and EG, respectively.

The importance of changes in soil water content was deduced based on the active-layer freeze–thaw characteristics. A sensitivity experiment using a land surface model showed that differences in pre-freezing soil water content had a particularly strong effect on the annual minimum soil temperature, being warmer when the soil is wetter (Figure 2). Futhermore, the effect of snowfall and surface organic layer thickness depend on soil water content. Both high soil water content and the understory vegetation growth might contribute to the stabilization of active-layer thickness.

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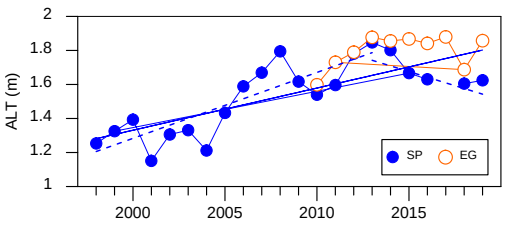

Figure 1. Variation of active-layer thickness (ALT)

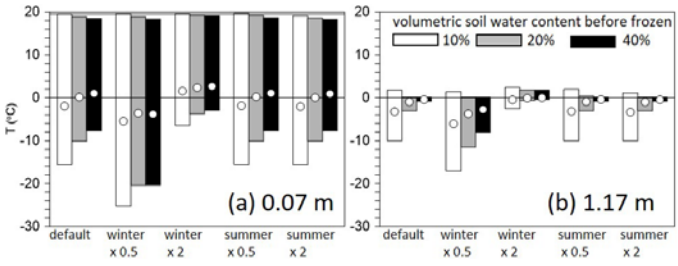

Figure 2. Simulated difference of annual range of soil temperature with annual mean (cilrcles) due to difference in volumetric soil water content before frozen and precipitation in depth (a) 0.07 and (b) 1.17 m.