Modelled (1990-2100) Variations in Active-Layer Thickness and Ice-Wedge Activity Near Salluit, Nunavik (Canada)

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Between 2016 and 2018, Gagnon and Allard (2019) investigated the impact of climate change on winter ice-wedge (IW) cracking frequency and IW morphology. In this study, they revisited 16 sites in the Narsajuaq valley (Canada) that were extensively studied between 1989 and 1991. Climate warming only started around 1993 whence mean annual air temperatures started to rise from -10 °C then to about -6 °C nowadays. This gave the unique opportunity to observe and measure changes by directly comparing field data with data pre-dating a climate warming of known amplitude. They found that based on IW tops, the active layer reached depths that were 1.2 to 3.4 times deeper than in 1991, which led to the widespread degradation of IW in the valley. Whereas 94% of the IWs unearthed in 1991 showed multiple recent growth structures, only 13% of the IWs unearthed in 2017 still had such features.

However, about half of the IWs in 2017 had ice veins connecting them to the base of the active layer, an indication that the recent cooling trend (2010-now) in the region was enough to reactivate frost cracking and IW growth. This shows that the soil system can respond quickly to short-term climate variations. For this study, we aimed to determine how changes in surface temperatures affected active-layer thickness (ALT) and dynamics over the past 25 years in order to understand the timing and reaching times of ground temperature thresholds for soil cracking and IW degradation. We used TONE, a one-dimensional finite-element thermal model, to simulate ground temperatures over the past 25 years. A monthly mean air temperature from a reanalysis (1948-2016) was combined with data from a weather station about 9 km west of the study area (2002-2018) to simulate the soil temperature profiles of four typical soil types found in the valley: thick sandy peat cover, thick peat cover, thin sandy peat cover, and fluviatile sands.

Our results show that ALT variations were predominantly controlled by changes in thawing season air temperature with regards to the previous year. As soon as 1998, the active layer had already reached the main stages of the IWs, i.e. the largest and oldest part composing the IWs, but it is only from 2006 that the main stages started melt until 2010, an exceptionally warm year. Based on soil temperature thresholds, our results show that IWs remained active until around 2006. This means that as the active layer deepened and caused IW tops degradation, freezing season temperatures were still cold enough to induce soil cracking and IW growth in width. After 2010, the cooling trend was enough to reactivate the IWs from as a soon as 2011. This study shows that prior to advanced degradation, IWs can melt substantively and remain active at the same time as
long as freezing season temperatures are cold enough to induce soil contraction cracking. However, it is likely that pulse events such as ground collapse will cause positive feedbacks contributing to rapid IW degradation before the soil completely stops cracking.