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Effects of soil moisture retention on ice distribution and active layer thickness subject to seasonal ground temperature variations in a dry loess terrace in Adventdalen, Svalbard.

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The active layer constitutes an important part of permafrost environments. Thermal and hydrological processes in the active layer determine local phenomena such as erosion and hydrological and ecosystem changes, and can have important implications for the global carbon-climate feedback. Permafrost degradation usually starts with a deepening of the active layer, followed by the formation of a talik and the subsequent thawing of permafrost. An increasing active layer thickness is therefore regarded as an indicator of permafrost degradation. The importance of hydrology for active layer processes is generally well acknowledged on a conceptual level, however the in general non-linear physical interdependencies between soil moisture, subsurface water and heat fluxes and active layer thaw progression are not fully understood. In this study, high resolution field data for the period 2000-2014 consisting of active layer and permafrost temperature, active layer soil moisture, and thaw depth progression from the UNISCALM research site in Adventdalen, Svalbard, is combined with a physically-based coupled cryotic and hydrogeological model to investigate active layer dynamics. The site is a loess-covered river terrace characterized by dry conditions with little to no summer infiltration and an unsaturated active layer. A range of soil moisture characteristic curves consistent with loess sediments is considered and their effects on ice and moisture redistribution, heat flux, energy storage through latent heat transfer, and active layer thickness is investigated and quantified based on hydro-climatic site conditions. Results show that soil moisture retention characteristics exhibit notable control on ice distribution and circulation within the active layer through cryosuction and are subject to seasonal variability and site-specific surface temperature variations. The retention characteristics also impact unfrozen water and ice content in the permafrost. Although these effects lead to differences in thaw progression rates, the resulting inter-annual variability in active layer thickness is not large. Field data analysis reveals that variations in summer degree days do not notably affect the active layer thaw depths; instead, a cumulative winter degree day index is found to more significantly control inter-annual active layer thickness variation at this site. A tendency of increasing winter temperatures is found to cause a general warming of the subsurface down to 10 m depth (0.05 to 0.26˚C/yr, observed and modelled) including an increasing active layer thickness (0.8 cm/yr, observed and 0.3 to 0.8 cm/yr, modelled) during the 14-year study period.