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Contrasting thermal responses of permafrost to winter warming events under different snow regimes in the subarctic

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Winter warming events (WWE) in the Swedish subarctic are abrupt and short-lasting (hours-to-days) events of positive air temperature that occur during wintertime, sometimes accompanied by rainfall (rain on snow; ROS). These events cause changes in snow properties, which affect the below-ground thermal regime that, in turn, controls a suite of ecosystem processes ranging from microbial activity to permafrost and vegetation dynamics. For instance, winter melting can cause ground warming due to the shortening of the snow cover season, or ground cooling as the reduced snow depth and the formation of refrozen layers of high thermal conductivity at the base of the snowpack facilitate the release of soil heat. Apart from these interacting processes, the overall impacts of WWE on ground temperatures may also depend on the timing of the events and the preceding snowpack characteristics. The frequency and intensity of these events in the Arctic, including the Swedish subarctic, has increased remarkably during the recent decades, and is expected to increase even further during the 21st Century. In addition, snow depth (not necessarily snow duration) is projected to increase in many parts of the Arctic, including the Swedish subarctic. In 2005, a manipulation experiment was set up on a lowland permafrost mire in the Swedish subarctic, to simulate projected future increases in winter precipitation. In this study, we analyse this 15-year record of ground temperature, active layer thickness, and meteorological variables, to evaluate the short- (days to weeks) and long-term (up to 1 year) impacts of WWE on the thermal dynamics of lowland permafrost, and provide new insights into the influence of the timing of WWE and the underlying snowpack conditions on the thermal response of permafrost. On the short-term, the thermal responses to WWE are faster and stronger in areas with a shallow snowpack (5-10 cm), although these responses are more persistent in areas with a thicker snowpack (>25 cm), especially after ROS events. On the long term, permafrost in areas with a thicker snowpack exhibit a more durable warming response to WWE that results in thicker active layers at the end of the season. On the contrary, we do not observe a correlation between WWE and end of season active layer thickness in areas with a shallow snowpack.