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Spatial and temporal variability of soil freeze-thaw cycling across Southern Alberta, Canada

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ABSTRACT

Soil freeze-thaw cycles play an important role in all aspects of agro-ecosystems, such as crop productivity, the evolution of the soil matrix, including trace-gas emissions. In regions that experience synoptic weather conditions throughout the winter, freeze-thaw cycles generally occur in one of two categories; seasonal or winter cycles. Current soil vegetation atmosphere models (SVAT ' s) often include a heat-transport soil freeze-thaw algorithm, but lack detail on complex interactions between the main driving variables. Boundary conditions for these models are often based only on a few climate variables and typically lack regional context. A nested statistical analysis was applied to identify the optimal set of environmental variables (via a stepwise regression selection procedure) to track soil freeze-thaw dynamics. Historical data collected between the years 2006-2009, for 17 long-term climate stations distributed across southern Alberta Canada was utilized. Cross-correlation between wind speed and maximum air temperature identified Chinook-driven freeze-thaw events, with such interaction varying significantly across the region and by soil depth. Climate-soil interactions were most significant predictors of soil temperature during winter months. The seasonal freeze-thaw cycle is estimated to vary between 112 - 131 days, consisting of 12 - 20 winter cycles (1 cm depth), and 1-5 winter cycles (5 cm depth) with average lag time of 26 - 112 days. Freeze-thaw prediction was greatly improved when higher-order climate interaction terms were considered. Our findings highlight the importance for soil-water and more complex ecosystem, SVAT models to better resolve regional-driven climatic trends. Alongside improved representation of regional trends aimed at reducing model-based uncertainty, such efforts are expected to, in tandem, help advance the geostatistical design, and implementation of agroenvironmental monitoring systems that combine in-situ and satellite/remote-sensing derived estimates of near-surface soil moisture.

KEYWORDS

Freeze-Thaw; Soil Temperature; Agro-Ecosystem Modeling; Regional Climate; Soil Science

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