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Evaluation of air-soil temperature relationships simulated by land surface models during winter across the permafrost region

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A realistic simulation of snow cover and its thermal properties are important for accurate modelling of permafrost. We analyze simulated relationships between air and near-surface soil temperatures in the Northern Hemisphere permafrost region during winter, with a particular focus on snow insulation effects in nine land surface models, and compare them with Russian station observations. There are large cross-model differences in the simulated differences between near-surface soil and air temperatures (ΔT; 3 to 14 °C), in the sensitivity of soil-to-air temperature (0.13 to 0.96 °C/°C), and in the relationship between ΔT and snow depth. The observed relationship between ΔT and snow depth can be used as a metric to evaluate the effects of each model's representation of snow insulation, hence guide improvements to the model's conceptual structure and process parameterizations. Models with better performance apply multi-layer snow schemes and consider complex snow processes. Some models show poor performance in representing snow insulation due to underestimation of snow depth and/or overestimation of snow conductivity. Generally, models identified as most acceptable with respect to snow insulation simulate reasonable areas of near-surface permafrost (13.19 to 15.77 million km2. However, there is not a simple relationship between the sophistication of the snow insulation in the acceptable models and the simulated area of Northern Hemisphere near-surface permafrost, because several other factors, such as soil depth used in the models, the treatment of soil organic matter content, hydrology and vegetation cover, also affect the simulated permafrost distribution.