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An iterative initialization procedure for transient ground temperature models with deep boundary conditions

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The initialization of deep soil thermal models is discussed here in view of two applications: (a) climate modeling, where land surface schemes comprise a soil thermal model; and (b) permafrost models.

Stevens et al. (2007) and Alexeev et al. (2007) have recently demonstrated that the bottom boundary condition placement can significantly bias ground temperatures as well as the partitioning of surface energy budgets in long-term climate simulations. Addressing this problem with a deeper soil model requires dedicated initialization techniques because simple spin-up would require prohibitively long time windows, especially in the presence of frozen ground and snow cover.

Physics-based models are increasingly used to estimate permafrost distribution as well as its temporal evolution, especially in mountain areas with high lateral variability of micro-climate and ground conditions. However, how can one know if the modeled presence/absence of permafrost in deeper layers is an artifact of the initialization or a valuable result? Strictly speaking, permafrost modeling with transient energy-balance and heat transfer models implicitly contains two steps: first, the finding of equilibrium conditions between the ground thermal profile and climate over one or several years and, then, possibly a transient simulation.

Mean air temperature and mean ground temperature at the depth of several meters are usually related in a non-obvious way, especially in regions subject to ground freezing and snow cover. As a consequence, we cannot reliably estimate the deeper temperature profile without running the soil model – which in turn requires realistic temperatures at depth.

In the method proposed to address this issue, equilibrium conditions are found by minimizing residuals between initial and final conditions of a model run over an initialization period and the near-surface part of the thermal profile. The success of this approach is judged by long-term model runs repeating only the conditions of the initialization period.

This method is expected to be important for permafrost simulations with energy-balance and heat-transfer models because it addresses the most fundamental question: “What temperature corresponds to the conditions prescribed?”. Similarly, a deeper bottom boundary condition placement in land surface models can only be useful if the deep temperature profile resembles reality.