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Investigating the effect of bottom boundary condition placement on ground heat storage in climate time scale simulations using ParflowE

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Heat and water fluxes are key variables affecting the atmosphere-land surface interactions as well as transpiration by plants and geochemical cycles. At climate timescales, the subsurface thermal regime may impact the land surface energy balance via the ground heat flux and associated temperature feedbacks. As a matter of fact, since there is no real lower energy boundary condition, except the natural geothermal heat flux, the subsurface may act as an infinite heat sink in case of a positive temperature trend at the surface. However, due to computational reasons, climate models incorporate a shallow subsurface domain, and thus a shallow temperature boundary condition, which generally is of the Neumann type. This leads to a cumulative ground heat flux of zero over large time scales, which is not realistic, in case of a trend in air temperature. Additionally, the convection term of heat transfer in the subsurface and the memory effect of soil moisture on energy transport is also neglected in climate models by simplified parameterizations.

Single soil column model experiments were performed with ParflowE as a subsurface model, which incorporates the more complete heat equation coupled to variably saturated flow, to study the effect of bottom boundary condition placement on ground heat storage and propagated temperature signals over large time-scale with respect to the hydro dynamic process and energy balances.

Simulations were carried out over one hundred years (2002-2101) using 4 simple soil columns with the same soil characteristic, lateral boundary conditions and atmosphere forcing, but differing in depth (12, 24, 75 and 150m). After a spin-up period, the models were forced with step-change air temperature and GCM model results namely the IPCC RCP 8.5 scenarios, in order to identify the climate change signals in the subsurface and the associated feedbacks at the land surface. While in the deep soil column, temperature profiles show a heat distribution which is mostly unaffected by the lower boundary condition, the shallow exhibits considerably larger temperatures in the in the shallow soil layers. Thus, over the 100 years, more than 0.45oC soil temperature difference at 12m depth was observed between the shallowest and deepest column simulations In contrast, the about three times more energy was stored in the 150m deep column in comparison to the 12m deep column.