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An insufficient subsurface depth biases the long-term surface energy balance in Land Surface Models

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The land subsurface stored around a 6 % of the Earth's energy imbalance in the last decades, being the second contributor to the partitioning after the ocean (90 %). Previous studies have shown that state-of-the-art Earth System Models (ESMs) remarkably underestimate the observational land heat uptake values. This underestimation stems from Land Surface Models (LSMs) within ESMs imposing too shallow zero-flux bottom boundary conditions to correctly represent the conductive propagation and land heat uptake with depth. However, non-significant temperature variability differences at the ground surface have been detected when these boundary conditions are prescribed deeper, so the physical process limiting land heat uptake was not yet identified. This study reveals that the underlying mechanism is the reduced incoming ground heat flux (GHF). To conclude this, GHF values coming from an ensemble of eight historical and RCP8.5 land-only simulations with different subsurface depths conducted with the LSM of the Max Planck Institute for Meteorology ESM (MPI-ESM), JSBACH, have been compared to GHF estimates yielded by a one-dimensional heat conduction forward model. Results show that GHF doubles when deepening the LSM from 10 to 25 m, saturating at a factor of 5 when the boundary condition is placed at approx. 100 m. The increase in the incoming GHF is mainly compensated by a global increase in the outgoing sensible heat flux (SHF), a small increase of the latent heat flux (LHF) in wet regions, and an increase in the surface net radiation in arid and semi-arid regions.