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The lower-boundary effect on simulated temperature signals in the terrestrial subsurface: An example from the ECHO-g GCM

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The position of the zero-flux lower-boundary condition in land-surface components of GCMs can significantly affect the character of propagating subsurface temperature signals and the subsequent amount of heat stored in the terrestrial subsurface. Here two analytic solutions to the one-dimensional diffusion equation are presented; the first is the well-known solution for an infinite half-space and the second is for a slab of finite thickness with a zero-flux lower-boundary condition. Differences exist between the two solutions in both phase and amplitude behavior with depth, the size of which is dependent on the period of the surface harmonic, the location of the lower boundary, the thermophysical properties of the subsurface and the depth at which the solutions are compared. The principal conclusion of this work is that shallow lower boundary conditions distort propagating subsurface temperature signals in a manner that is not representative of the actual behavior of heat transport in the Earth's terrestrial subsurface. The results suggest that GCMs have applied lower boundaries that are too shallow and can incur a significant amount of error in their simulations of evolving subsurface thermal fields. This finding is confirmed by demonstrating the presence of altered amplitude and phase behavior in subsurface temperature signals simulated by the ECHO-g GCM. This model uses a 10 m lower-boundary condition and therefore is likely to be less affected than other GCMs that typically apply lower boundaries

around 2-4 m. Nevertheless, temperature signals in the ECHO-g millennial integration display altered amplitude and phase behavior at frequencies as high as 0.2 yr-1, the effects of which increase with decreasing frequency.