Geophysical Research Abstracts
Vol. 20, EGU2018-17035-1, 2018
EGU General Assembly 2018

Increasing the depth of a Land Surface Model: implications for the subsurface thermal and hydrological regimes.

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The representation of the thermal and hydrological state in Land Surface Models (LSMs) is crucial to have a realistic simulation of subsurface processes and the coupling between the atmo-, lito- and biosphere. An important factor for the LSM realism is the depth of the soil allocating space for subsurface processes and hence, land-climate feedbacks. This work addresses the influence of soil depth on the long-term climate variability and land-climate coupling. The concept of soil depth used herein is twofold, defining it as available space for energy storage on the one hand, and water storage on the other hand. Changes in any of them influence the simulation of land-air interactions and subsurface phenomena, e.g. energy/moisture balance and storage capacity, freeze/thaw cycles or permafrost evolution.

The "thermal depth" refers to the depth of the zero-flux Bottom Boundary Condition Placement (BBCP). There is evidence for the current generation Earth System Models (ESM) inaccurately simulating subsurface thermodynamics by having LSM components with a BBCP too close to the surface. In shallow LSMs, the amplitude and phase of the energy propagation with depth and the spatial (vertical) and temporal variability of subsurface temperatures are distorted. In this study, we increase the BBCP into JSBACH - the LSM component of the MPI ESM. Four subsurface layers are added progressively to increase the soil depth from 10m (5 layers) to 275m (9layers). The depth of the BBCP has also implications for the hydrological regime, in which the soil moisture is sensitive to depth changes in the thermal scheme. The ‘’water depth” is specified by the parameter datasets that characterize the spatial distribution of root and bedrock depths. Thus, it defines the space for water storage available for hydro-climate interactions. We use two different datasets of soil parameters to assess the sensitivity JSBACH, with major implications for the vertical distribution of soil moisture. Both in the cases of BBCP and water depth changes, we explore the sensitivity of the LSM from the perspective of changes in the soil thermodynamics, energy balance and storage as well as the effect of including freezing and thawing processes.