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Impact of Parameter Variability and Grid Coarsening on Ensemble Simulations of a Coupled Land Surface-Subsurface Model with Implications for Data Assimilation

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The demands for better representations of physical processes in numerical models and the rapid evolution of computing power have boosted the development of models that can describe the terrestrial water cycle in a coupled approach. Such coupled models simulate water and energy fluxes in the atmosphere, on the land surface, and in the subsurface in a physically consistent way, albeit with massive computational costs and high uncertainty of all parameters involved. The main objective of our research is the development of a suitable, ensemble-based data-assimilation framework to update model states and/or parameters of a coupled land surface-subsurface model. Towards this end, we first had to address the question of how to generate an adequate ensemble. As simulation system, we used the Terrestrial Systems Modeling Platform TerrSysMP, which couples the community land-surface model (CLM) and the subsurface model Parflow. The model domain covers a rectangular area of $1\times5\text{km}^2$ and has a uniform depth of 50m. Streams are defined along the northern, southern and western boundaries of the domain. The subsurface material is divided into four main units, and the top soil layers consist of three different soil types, each with different vegetation. The reference model, which we consider our synthetic truth, has a horizontal grid resolution of 10m. For the ensemble, we coarsened the grid to a resolution of 40m. We could afford 128 realizations with the available computing resources, considering that each member had to undergo a spin-up phase. Grid coarsening led to smoothed topographical features. Since local grid refinement is not implemented in Parflow, the rivers were wider in the coarser model. We divided the ensemble in four groups: Members of the first group considered spatial variability in the saturated hydraulic conductivity, while soil parameters were considered homogeneous within soil units, and plant physiology was identical to that of the reference model. In a second group, soil parameters were treated as spatially variable fields and subsurface parameters were homogeneous within each rock unit. The third group contained variations in plant physiology and homogeneous soil and subsurface parameters. The last group was a combination of the others. We conclude that grid coarsening has a major effect on overland flow, river discharge, and river infiltration/exfiltration and evaporation rates. River interactions with the subsurface could be compensated, to some extent, by scaling river parameters, but the overestimation of evaporation rates could not be fixed. The suitability of river-related data of coarsened models for data assimilation is still unclear. For each ensemble group, we could define a distinctive response in the simulated states and fluxes, and therefore establish the relevance of certain groups of parameters for specific processes within and between compartments. Finally, the observed ensemble spread of several model states and fluxes suggests that our ensemble is suitable for a coupled data assimilation.