Coupling a three-dimensional subsurface flow and transport model with a land surface model to simulate stream-aquifer-land interactions (CPv1.0) [MS No.: gmd-2017-35]

Responses to review comments

Anonymous Referee #1:

The authors present a new coupled version of CLM4.5 and PFLOTRAN, and demonstrate the impacts of resolution, horizontal fluxes, and river stage height in simulating groundwater levels and turbulent fluxes between the land and the atmosphere.

The authors demonstrate that the new model is capable of simulating the observed water table depth, independent of the model resolution. The authors show PF-CLM results when there is no lateral subsurface exchange. Does this produce the exact same results as CLM without PFLOTRAN? If not CLM should be included in the manuscript. If so the authors should state that running PF-CLM without horizontal transfer gives identical results to CLM.

Response:

Thanks for the suggestion. We understand that the standalone CLM4.5 could serve as a good reference for most readers. Therefore, we have included a figure from the CLM4.5 simulation in the supplementary material (i.e., Figure S4) and added discussions on differences in section 5 of the revised manuscript for clarity.

For information, the reasons that a CLM4.5 standalone was not included in the original manuscript were:

(1) The subsurface domain in CLM4.5 for hydrologic processes only extends to 3.8 m below the surface, while in CPv1 subsurface hydrologic processes are simulated ~30m below the surface;

(2) As reviewed in section 2.2 of the original manuscript, CLM4.5 uses TOPMODEL-based parameterizations to simulate surface and subsurface runoff, as well as mean groundwater table depth using formulations derived from catchment hydrology that do not apply at the field site of interest;

(3) The key hydrologic progresses (i.e., the exchange of river water and groundwater at the east boundary and lateral transfer of water at all other boundaries) that affect the hydrologic budget of the system are missing from CLM4.5.

The description of the technical details of the coupling needs more explanation. It is cleat that only the soil moisture and hydraulic properties as passed between CLM and PFLOTRAN. However how does this work given that the vertical discretization of CLM differs from PFLOTRAN? The vertical resolution of the subsurface (PFLOTRAN) component is only 0.5 *meters, while CLM uses layers from mm to m. How does this impact transpiration? Is the default rooting depth used in CLM? How are the 0.5 meter thick layers mapped to the much thinner layers? Does CLM compute freezing and thawing? Which processes are no longer used by CLM in the coupled version?*

Response:

In response to all reviewers' comment regarding model coupling, we have significantly revised the technical details about model coupling in Section 2.3 and schematic describing the model coupling in Figure 1. While the updated section addresses all of the questions raised by the reviewer, we summarize the answers here. The model coupling interface is able to accommodate different vertical and horizontal resolution between the two models. In our present work, both models had the same horizontal resolution, but different vertical resolution. CLM used the default, exponentially varying vertical discretization, but PFLOTRAN had a uniform 0.5 [m] vertical spacing. The vertical extent of the domain in PFLOTRAN is deeper than the CLM domain. The model coupling interface uses conservative interpolation scheme to remap data between two model grids.

Although a study of the changes in computed transpiration due to differences in vertical resolution between CLM and PFLOTRAN is an interesting research investigation, it is beyond the scope of this work. The coupled simulation used the default rooting distribution of CLM. Although PFLOTRAN has a mode that can explicitly handle liquid and ice phase (Karra et al., 2014), in this work, freezing/thaw dynamics was handled by CLM. In this work, CLM's 1D model for flow in unsaturated (Zeng and Decker, 2009) and saturated (Niu et al., 2007) zones are replaced by PFLOTRAN's 3D flow model.

I am having trouble understanding why the grasses away from the river always have near zero latent heat flux (Figure 7a) while the bare ground has a larger latent heat flux? This explains why the latent heat flux only differs over the bare soil surfaces between CLMPF2m and CLMPFv2m. I fail to understand why the bare soil has a higher latent heat flux than the vegetation, especially given that the moisture available to the roots from horizontal transfer should be even greater than the moisture at the surface. The authors need to explain if this is the expected behavior in CLM, or if it is due to the coupling between PFLOTRAN and CLM.

Response:

It is a known problem that, in CLM4 and CLM4.5, ET could be enhanced when vegetation is removed. This ET enhancement over bare soil has been documented as a counter-intuitive bias for most unsaturated soils in CLM4 and CLM4.5 simulations (Lawrence et al., 2012;Tang and Riley, 2013a). Tang and Riley (2013a) explored a few potential causes for this likely bias (e.g., soil resistance, litter layer resistance, and numerical time step). They found the implementation of a physically based soil resistance lowered the bias slightly, but concluded that the bias remained (Tang and Riley, 2013b). Meanwhile, in studying ET over semiarid regions, Swenson and Lawrence (2014) proposed another soil resistance formulation to fix this excessive soil evaporation problem within CLM4.5. While their modification improved the simulated terrestrial water storage anomaly and ET when compared to GRACE data and FLUXNET-MTE data, respectively, the empirical nature of the soil resistance proposed could have underestimated the soil resistance variability when compared to other estimates (Tang and Riley, 2013b).Therefore, this is expected behavior in CLM rather than being introduced by the coupling between CLM and PFLOTRAN. We have added discussions in section 5 of the revised manuscript.

Figure 6 should be shown as the difference between the observations and the simulations. This will show much more information concerning how the simulations differ.

Response: We have made changes as suggested. Please check Figure 7 in the revised manuscript for details. We also moved the original figure to the supplementary material as a reference for the readers (i.e., Figure S5).

References

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