Weak sensitivity of the terrestrial water budget to global soil texture maps in the ORCHIDEE land surface model

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Reply to anonymous Referee #2

Overall Comment

This study investigates how a land surface model behaves against different global sets of soil parameters in terms of the terrestrial water balance. The experiment configurations follow the protocol of an ongoing international project, Soil Parameter Model Intercomparison Project. It concludes that the choice of the soil texture map is not crucial for large-scale modeling. The manuscript is well-written in a concise form, and their findings are important to our community. I encourage the HESS journal to host this study, but the current version of the manuscript would not be at level to be accepted because of some hasty explanations and not enough interpretation and discussion.

We would like to thank the reviewer for taking the time to go through the paper, and for the relevant comments. According to all the three reviews that we received, we decided to make some substantial changes to the paper, in particular, the scientific question of the paper will be more clarified and new sub-sections will be added. A detailed presentation of the new structure of the paper is presented in the answer to Referee #1. In the following, we will provide a response to every point raised by Referee #2.

Specific Comments

13 : “medium texture” is not a clear term here.
Medium textures are the loamy textures, with medium dm (median diameter). To clarify this in the abstract, we will use the term loamy texture, which is clearer

16 : Please provide reason or speculation why it “is not crucial”. If not, it could mislead readers to consider soil parameters are not important, which is not true.
The referred sentence relates to the soil texture maps and the not to the soil parameters. The specific reason is given by the previous sentence: “The three tested complex soil texture maps […] result in similar water budgets at all scales, compared to the uncertainties of observation-based products and meteorological forcing datasets”. But this conclusion will be refined by underlining the areas where the choice of the soil texture map makes a significant difference, as detailed in a new subsection 3.4 “Regional zooms on greatly impacted areas”, following the suggestion by Referee #1.

81 : Please add data citation for GSWP3-v1 H. Kim. (2017). Global Soil Wetness Project Phase 3 Atmospheric Boundary Conditions (Experiment 1) [Data set]. Data Integration and Analysis System (DIAS). https://doi.org/10.20783/DIAS.501
We will add this reference to the description of GSWP3-v1.

93 : Rather “coarse and fine” than “medium and extreme”?
Lines 92 and 93 will be changed to: “In addition, we tested four spatially uniform texture maps, corresponding to the Loam, Loamy Sand, Silt, and Clay texture classes (EXP6 to EXP9), to analyze the importance of spatial variability of soil texture on the global water budget.”

133 : Please add the definition of “soil-moisture” which is sampled from each soil texture class which has a similar range of precipitation. Also, specify the sampling depth; top-soil, rootzone, full-column or any specific depth?
The simulated soil moisture corresponds here to the whole soil column (2m depth), as will be specified in the revised manuscript. As for the clustering by soil texture and normalization by mean precipitation, the latter is only used for the fluxes (see line 125), and not for soil moisture. We will add that this normalization is performed at point scale, using the pluri-annual mean of precipitation.

142 – 145 : Please provide additional information how the model treats the root uptake and root-zone soil-moisture. Also, speculations on the role of groundwater capillary action would be a very important aspect, too.
In ORCHIDEE, a root uptake function (describing the water extraction ability of roots) is used to calculate transpiration; it is a function of both the soil moisture profile and root density profile. The latter one follows an exponential decrease with depth at a rate depending on the plant functional type. We will add this in the model description, in section 2.1 of the new version of the paper.

Regarding capillary rise, the standard version of ORCHIDEE used here considers free drainage at the soil bottom, which corresponds to the assumption of uniform soil moisture profile below the soil bottom, i.e. groundwater does not impact soil moisture through capillary rise. This will also be added in the model description section.

149 : How does leaf area index affect soil evaporation; interception loss, radiative transfer in canopy? Citing previous research would be helpful to show soil evaporation “strongly depends on other factors”.
In ORCHIDEE, LAI has an important influence on the partition between soil evaporation and transpiration, via the fraction that is effectively covered by foliage, which increases exponentially with LAI with a coefficient of 0.5, also controlling light extinction through the canopy (Krinner et al. 2005). This fraction contributes to transpiration and interception loss, while the complementary fraction is assumed to be bare of vegetation, and only contributes to soil evaporation. This explanation will be added to the description of the ORCHIDEE LSM (section 2.1), thus complying with a request by Referee #3.

To support the sentence of lines 148-149, we will also add the following references: Martens et al. (2017) and Wang et al (2018) regarding the anti-correlation between LAI and soil evaporation (further supported by the spatial correlation of -0.32 between these two variables in our simulation EXP2); the negative impact of vegetation on soil evaporation can also develop owing to the litter, which exerts a resistance to this flux (Ogée & Brunet, 2002; Sakaguchi & Zeng, 2009). However, the dependence of soil evaporation on climatic variables (temperature, potential ET) and soil moisture will not be expanded, as it is very well established.

158 – 163 : Only a part of Figure 4 has been touched. I suggest the authors to add in-depth interpretation of this figure. For example, the change of evaporation could be compared with of soil-moisture – (transpiration + total runoff). It is not recommended, but to discard this paragraph and Fig. 4 would be another option.

We agree with Referee #2 that Figure 4 was too briefly discussed. This figure is intended to show how the simulated variables change when only soil texture changes, to better analyze the model's response to the different soil textures. We propose to expand the last paragraph of section 3.1 addressing this Figure:

"By focusing this time on the point-scale changes induced by changing the soil texture map (from Reynolds to SoilGrids), Figure 4 highlights that the simulated soil evaporation decreases from fine to coarse textures, so that capillary retention, which is the main limiting factor to soil evaporation in ORCHIDEE, depends more strongly on soil moisture (higher for fine soils) than on intrinsic capillary forces (stronger for fine soils). We fail to see this behavior in Figure 3, which is likely due to the greater impact of diverse climatic conditions and vegetation associated with every soil texture. Figure 4 also confirms the results of Figure 3 for the other variables, including the decrease of soil moisture with coarser soils and the greater impact of soil texture on runoff variables (surface runoff and drainage). In particular, we find that replacing fine textures with coarse textures (above the first diagonal of the matrices) results in higher drainage (due to the higher permeability of coarse-textured soils) and lower surface runoff, with changes that can exceed 1mm/d in absolute value for some textural changes (all involving medium texture classes). As a result, less water is available in the soil, which leads to less soil evaporation, further leading to more transpiration (Fig. 4bc).

The convex behavior of total runoff with soil texture can also be seen in Figure 4h, which is antisymmetric along the two diagonals, thus defining four different kinds of total runoff change to soil texture change. This behavior results from the fact that total runoff sums up two variables of opposite response to soil texture change (surface runoff and drainage), the net response depending on the dominant component. Hence, changes to medium textures from either coarse or fine textures (left and right red triangles in Fig. 4h) lead to reduced total runoff, owing to reduced surface runoff in the first case, and reduced drainage in the second. In contrast, changes from medium texture to either coarse or fine textures lead to increased runoff (bottom and top blue triangles in Fig. 4h), owing to increased surface runoff or drainage, respectively. This pattern thus means that the medium textures correspond to the smallest total runoff. By means of long-term water conservation, the opposite patterns are found for total evapotranspiration changes (Figure 4d), because of the opposite responses of soil evaporation and transpiration to soil texture, and supporting the concave response of this flux to soil texture found in Figure 3."

175 : "coarse or clay" would be "coarse or fine" or "loamy sand or clay".

"coarse or clay" will be replaced by "coarse or fine".

175 – 177 : To me, evapotranspiration of EXP6 and EXP7 also seem out of the observed range.

It is true that land mean evapotranspiration of EXP6 is out of the observed range, but the one of EXP7 seems acceptable if we accept that the three estimates have an error margin, as shown for the estimates of Rodell et al (2015) for both total ET and total runoff, for which EXP6 and EXP7 fall within the confidence interval. Thus, when confronting the estimates of both mean total ET and total runoff over land, only EXP8 and EXP9 are clearly out of the observed range. We will make this point clearer in the revised version of the paper.

182 – 183 : Please specify regions.
As explained in the response to Referee #1, the structure of the paper will be changed and a new sub-section dedicated to regional zooms on greatly impacted regions will be added, these regions include: Central America, Middle-East and India, Tropical South America and Central Africa. Lines 182 -183 will be changed accordingly.

185 – 186 : To me, it does not seem to have a larger variability to the other fluxes (e.g., total runoff), particularly.
We agree with the referee, but we are not comparing here the variability of evapotranspiration to the one of other variables. What we try to explain at lines 185-186 is the orange pocket in Fig 6a, with a decrease of ET when changing the soil texture to a uniform Loam, while we have previously shown that the medium textures correspond to the largest ET (cf. Figs 3 and 4, with the concave response of ET to soil texture). This region corresponds to a Clay Loam in SoilGrids (Fig. 1c), which is also found in many other regions (e.g. extensively in South America), without any significant change in ET when changing SoilGrids to the uniform Loam map. The underlying reason is thought to be the large variability of evapotranspiration within the Clay loam and Loam texture classes (Figure 3b), which makes it possible to have a local decrease of ET when changing soil texture from Clay loam to Loam despite the opposite relationship between the central values of these classes in Figure 3. The incriminated sentence will be rephrased based on the previous one, and moved to the new section of the revised version of the paper 3.4, as explained in answer to Referee #1.

209 : Please add “at the global scale”
It will be added in the new version of the paper.

References:

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