Response to Reviewer 2 for "Investigating soil moisture-climate interactions with prescribed soil moisture experiments: an assessment with the Community Earth System Model (version 1.2)"

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We are thankful to the reviewers for their positive comments and their feedback, which helped us to improve the manuscript. We added the following main changes to the revised manuscript:

- Simulations with a new methodology to prescribe soil moisture, and its discussion. The new methodology prescribes soil water and ice but lets the model determine the relative proportions of the two components (PRES_FRAC).
- A more thorough discussion of the skewed soil moisture distribution, and the temperature response to the soil moisture prescription
- All figures were enlarged. Some figures were updated to include the new prescription method (Figure 1, Figure S4, and Figure S5). Figure 2 was enhanced to include time series of soil moisture for a whole year for an example grid point. Figure S9 was moved to the main text and is now Figure 6. Figure S6 and Figure S7 were removed to reduce the number of figures in the supplementary material. We added a new Figure S6 to show the ground heat flux anomalies for all seven simulations.
- Some minor adaptations to the manuscript text.

Reviewer 2 (Jeanne Colin)

General comments
This paper investigates some of the issues related to the experimental protocol of the "Land Surface, Snow and Soil Moisture Model Intercomparison Project" (LS3MIP). Several methods to prescribe the soil moisture conditions are tested, and the results are analyzed in terms of water balance perturbations. This constitute a new diagnostic that should be quite inspiring for other modelling groups. The study is carefully carried out and well written. And it is highly relevant in the context of the coming LS3MIP exercise. I recommend a publication, although I have some minor comments.

B1: We thank the Jeanne Colin for these positive comments.

Specific comments
1. p. 4, lines 1-15 (description of the various methods of prescription) The authors consider the possibility of prescribing either the liquid water content only, or the liquid and ice contents separately. There is (at least) another option in which the total amount of soil moisture (liquid + ice) is prescribed and the partition of ice and water is computed accordingly to the model's proportion of liquid and ice at a given time step (i.e. before the value is prescribed). This what we did in Douville et al. (2016) and we tend to think this method can prevent most of the disturbance in the energy balance you observe with the PRES_LIQ+ICE method. It would have been interesting to test it. But since it was not, it could be worth mentioning.

B2: We also performed such simulations with CESM/ CLM, and we added them to the paper as PRES_FRAC_MEAN and PRES_FRAC_MEDIAN. Unfortunately, this also led to large temperature/ ground heat flux anomalies in CLM4. We suspect that vertical liquid water transport in the soil is responsible for this (when soil ice melts the water ends up in a different soil layer than where it originates from and the fraction of soil ice is still 100 %, thus soil ice is added). However, we do think that this technique is valuable, and that this is a CLM4-specific problem.
Given Figure 2 in Douville et al., 2016 (especially "FR - FNF", and "PNP - PR"), we are confident that your simulations do not suffer from this problem.

2. p. 4, lines 4-8
I had a hard time understanding the description of the PRES_LIQ method. Figure 1 definitely clarifies things, but the written explanations should be improved. For example, the text could explicitly mention that the total soil moisture content is converted

into liquid water to be prescribed. The authors could also write that below zero, both the liquid water and ice contents are let interactive.

B3: We rewrote the description as suggested on P4, L6:
Furthermore, we propose an alternative approach where SM is only prescribed when the soil temperature is above 0° C (PRES_LIQ). If the soil is frozen, LIQ and ICE are both computed interactively. The climatological total SM (i.e. LIQ + ICE) is converted into LIQ for the prescription.

3. p.7, lines 26-27
"Interestingly, the regions with large amounts of net added SM coincide with regions where we find the strongest Txx reduction in Figure 4". Could you give some physical explanations of this finding?

B4: Please see answer B5.

4. p.7, lines 26-27
The reduction of TXx found in southwestern Europe in figure 4.d does not match any perturbation of water balance in figure 5.d. Can you comment on that?

B5: We added a paragraph addressing this and the last comment on P8, L17:
The regions with large amounts of net added SM coincide with regions where we find the strongest TXx reductions in Figure 4, a consequence of the (muted) land-atmosphere coupling. These regions also show large positive anomalies in evapotranspiration, which is responsible for the large amounts of added LIQ, as well as the reduction of the sensible heat flux, which in turn leads to lower TXx. Interestingly, TXx decreases almost at all land grid points, while in many regions more water is removed than added. This is explained by evapotranspiration which increases in most land areas (not shown) thus indicating that the SM prescription ensures availability of water even during hot and dry periods.

5. p. 7 line 32 to p.8 line 4
Do you have some insights as to why the PRES_LIQ_MEDIAN method leads to a smaller imbalance than the PRES_LIQ_MEAN one? It would help to plot the distribution function of SM, as in figure 2.a, for grid points where the differences between the two methods are the greatest. Let's say in India where large amounts of water are added in PRES_LIQ_MEAN and in Indonesia or Brazil where water is removed.

B6: We added a short discussion in the paper on P8, L29:
Regions where less water is added in PRES_LIQ_MEDIAN than

PRES_LIQ_MEAN also show substantially smaller evapotranspiration, because the median SM climatology is smaller than the mean. On the other hand, regions where more water is added with the median SM climatology, often show more rainfall, especially northern Brazil.

Technical corrections
1. The figures should be enlarged.

B7: We updated the figures.