Manuscript: Permafrost sensitivity to soil hydro-thermodynamics in historical and scenario simulations with the MPI-ESM

Major remarks

Using the fully coupled MPI-ESM, the authors analysed the impact of different soil scheme setups on the simulation of various permafrost features and their trends under global warming conditions. The various setups of the JSBACH land surface scheme (LSM) comprise differences in soil hydrology, soil thermal dynamics and considered soil depths. They compared their results with results from the current CMIP6 ensemble and highlighted the importance of a deep LSM soil depth for more reliable projections of deep permafrost. Such a deep soil depth is currently not used in any of the existing operational ESMs.

The study is very interesting and provides some insights why CMIP6 models behave so differently in their simulation of the current and futures states of Arctic permafrost areas. The paper is generally well written, having an appropriate number of figures. However, there are a few points where the manuscript may be improved. This is especially the case for the abstract. Currently, the abstract starts with a paragraph comprising a general introduction to the permafrost under global warming topic, one sentence on exploring the response of MPI-ESM, a short method section and some general description of results. I believe that the abstract can be strongly improved by sharpening the text regarding research gap and objective of the paper as well as in summarizing the most important results. This can be done, e.g., by starting with about two sentences on the existing research gap followed by a precise statement of the research objective of the paper (e.g. gaining more knowledge on….). Here, exploring MPI-ESM response is a mean to fulfil this objective. Then, this can be followed by the method description and the results. For the results, I suggest pointing out the main qualitative results instead of listing numbers. I also would regard the relevant result that 'LSM depth plays a substantial role in determining future ALT.'

Partially, the manuscript text comprises a lot of number crunching (especially in lines 356-376). It should be checked whether this may be reduced by inserting appropriate tables.

In summary, I suggest accepting the manuscript for publication after minor revisions are conducted.

Minor remarks

In the following suggestions for editorial corrections are marked in *Italic*.

Line 89
… shown by *the latest* ESMs in *climate scenario* simulations.

Line 101-103
For this work, an ensemble of fully-coupled simulations *has been developed, using both* the standard … … physics.

Line 158-159
In *all simulations*, the ocean component was *initialized using a restart* from a long-term ocean simulation *stabilized* to pre-industrial conditions.

Please replace ‘all the simulations’ or similar instances by ‘*all simulations*’ throughout the paper!

Line 175
… when there *is* snow cover.

Line 197
… 3 m and *an* ALT …

Line 208-210
To address this *question, we are* trying to minimize the uncertainty associated with the PE definition selection *by estimating* the PE evolution for the *nine* historical + SSP5-8.5 simulations of the *MPIESM-PePE using* two…

Fig. 4 caption – last sentence
… SSP5-8.5 *scenario* (2015-2100) *simulations.*

Line 316-318
The thermal diffusivity of snow is low due to its low heat conductivity (… …) *and relatively high volumetric heat capacity* (… …). *This hinders heat* transfer and effectively *insulates* the soil beneath the snow cover.

Line 324
… also *occurs in* the absence …

Line 326
… helps *to* smooth …

Line 343
Here, when soil …

Line 350
… Fig. 7c), *a* depth …

Line 352
… therefore of *a* zero-curtain …

Line 356-376
This part comprises the listing of too many numbers so that is not fluently readable. I suggest implementing a suitable table with those numbers and then refer to it in the text.

Line 364
… for DRY *is shown in* Fig. 8.

Line 375
… than *in* 1995-2014 …

Figure 8 and 9
The colour legend comprises too many colour steps so that it is partially difficult to visually separate those steps. See also comment to Fig. 11.

Figure 8 and 9 captions
… 18L). *This is represented by the spatial* distribution of the *final* simulation year *in* which ALT is … … for *each* MPIESM-PePE simulation.

Figure 8 caption
The time evolution for *the* historical and SSP5-8.5 experiments is shown in *each* case.

Line 388-389
Nevertheless, it increases the LSM depth when resolving vertical heat diffusion*, which is the prevailing factor* in …

Line 440-441
Under the SSP5-8.5 scenario, the PE loss shows no *signs of stabilising*, *either* for the MPIESM-PePE *simulations* or the CMIP6 *simulations*.

Figure 11 (and Figs 8 and 9)
Separating the lines is difficult in many panels, hence, the figure should be improved.

I recommend enabling a better comparability to Figs. 8 and 9. This, e.g., might be achieved by reducing the number of colour intervals, especially for the 21st century. For the latter, 20-years intervals are appropriate. Here, I would use clearly noticeable colour/interval borders that are consistent with the panels in Fig. 11, i.e. at 1900, at 2014, 2040, 2060, and 2080.

Figure 12 caption
Remove sentence: In this study …. 2.3.3). The caption should only describe the figure and its content.

Figure 12
I suggest plotting the MPI-ESM-PePE members on top so that they can be better distinguished. Identifying single symbols is not necessary for the CMIP6 models so that they may be partially covered.

Line 524
… profile *for 6*-8% of

Line 532-534
In fact, CMIP6 models *with* LSMs deeper than 40 m show the *smallest differences in ZAA-TTOP PE,* indicating that ESM simulations with deep LSM vertical schemes *are better at projecting* the future …

Line 551
… *Helmuth* Haak …