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The Cryosphere Discussions

Interactive comment on "Weichselian permafrost depth in lowland Europe: a comprehensive uncertainty and sensitivity analysis" *by* J. Govaerts et al.

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General Comments: *Overall, this work is understandable and presents a methodological approach to assign estimates given a large range of uncertainty. However, there are some areas which seems to give superfluous information and unnecessary details while some other sections require more explanation and greater detail.*

We would like to thank reviewer 2 for her remarks; we have tried to address them as good as possible. We believe this has improved the quality of the manuscript.

*I think it is important to include more detail on the parameters of the model and subsurface characteristics and how they vary. At one point, thermal conductivity is said to

be averaged. However, from the model description they seem to change as a function of frozen/unfrozen. It is not clear what varies spatially, either from polygon to polygon, or vertically through the 1-d mesh. *

We have tried to make this more clear. See below in the specific comments.

*The porosity is mentioned plenty of times but is it stated that the model assumes full saturation and that the porosity equals water content? *

We state that vadose zone is not taken into account, which implies full saturation. We have stated it more explicity now.

*If this study is to be added into the inventory of past permafrost estimates, the understanding of the model construction, assumptions, initialization, and parameter settings should be very clear. This allows future research to make fair comparisons. *

We have tried to do this by adding more detail on the model domain and parameters in a new paragraph (2.5).

The description of the uncertainty analysis on page 10 should be condensed. It distracts the reader.

As acknowledged by the editor and reviewer 1, the uncertainty and sensitivity analysis is the main asset of this paper. The description on page 10 is necessary to frame the need for uncertainty analysis within the context of radioactive waste disposal. Also, we believe that the description of these techniques is already concise and does not go too much into mathematical details. We prefer to leave it as it is.

Specific Comments: *P2, L1-2: This first sentence needs a reference.

This has been done.

*P2, L11: "periglacial conditions will reappear". Reappear where? At current state, periglacial conditions are existing already. Please be more specific at this kind of suggestion.

We have added some clarifications at this point.

*P5, L32: What do you mean by “conservatively” neglected?

Conservative means that including these effects would most likely decrease permafrost depths. As such, a safety margin on the results is implicitly included.

*P6, L13: This is the point at which the vertical description of the model is presented and it is overlooked. What is the depth and how does the mesh reflect the varying subsurface characteristics? This is confusing with your description on P6, L31. How deep is the lower boundary?

We have added a paragraph which treats all this in detail (section 2.5) including a figure which should help to understand how the model domain is set up.

*P6, L22: “The input temperature is held constant for the entire country”. Do you mean for initialization or a spin-uo?. Surely, the temperature forcing changes temporally and spatially so what is this sentence describing? I suppose the intial setup?

“The input temperature is allowed to change temporally, but held uniform spatially for a given time step.“ This has been added.

*And what is the input temperature?

We have replaced input temperature with ‘forcing’ temperature, as suggested.

*P6, L30 to P7, L2: I don’t understand these dimensions and the following descriptions. This section should be described with improved clarity.

We have restructured this sentence in order to make it more clear.

*P7, L14-15: REGIS model should have a reference.

A reference to the REGIS II model has been added.

*P8, L3: you may want to replace “input” here, and in other spots in manuscript. With the term “forcing”.

This has been done.

*P9, L13: ..as soil input data..” is vague. Maybe write surface temperature data or land temperature forcing.

This has been done.

*P9, L17: “shielding effect of snow and temperature” does not make sense

. . .and temperature has been removed.

*P9, L30: “average thermal conductivity values”. Does this mean there is only one thermal conductivity value per polygon or just for the purpose of calculating a thermal gradient?

Yes, the thermal conductivity of the Rupelian Clay overburden is averaged across the entire depth. This is used in the simulations.

*P12, L3-5: The T1 to T26 are simply time intervals or snapshots of the transient simulation? Is this a variable you control for? A table should be provided that relates the T variables with their time interval.

“T1 to T26 are variables which are used to control the magnitude of the various temperature plateaus during the Weichselian temperature cycle. This allows to account for the actual parameter uncertainty on the temperature as well as the nation-wide spatial parameter variability.” Is stated in section 2.6.3. They have been added to table 2.

*P14, L9: You state that a higher parameter will cause a larger permafrost depth but how is this possible if for example, the geothermal heat flux parameter is high, which in turn would cause less permafrost to develop ?

“A positive correlation coefficient (SRC/PCC) means that a higher value of the parameter will cause a larger permafrost depth and vice versa. “. So if an increase of the parameter value increases the permafrost depth, the sensitivity coefficient is positive. If an increase of the parameter value decreases the permafrost depth, the sensitivity

coefficient is negative.

*P14, L1-9: If you state earlier that you use SRC for this study (P12, L20), why are you discussing PCC?

This was a mistake, it has been corrected.

*P14, L16: How can you say that geothermal heat flux is the main driving force of degradation? Is it not the temperature forcing at the surface? Is this accounted for by the R2? If you find that the geothermal heat flux accounts strongly for permafrost warming MORE than the surface temperatures, this is an important finding that should be clarified and explained.

It can be seen in figure 8, that during the timeframe of decreasing permafrost depth (for instance 10 – 20 ka BP, 40 – 50 ka BP) the SRC of geothermal flux becomes larger than those of the temperatures relevant for that time period. It must be noted that the SRCs account for the sensitivity of the permafrost depth. So it makes sense that the geothermal flux will act more severely at the base of the permafrost rather than the surface temperature, which will force the melting at the top of the domain. This is particularly true when the permafrost front has reached greater depths. We have changed the sentence in the following way in order to be more specific about the influence of the geothermal flux: “However, when the surface temperature again rises and the permafrost starts to degrade, the geothermal flux acts as the main driving force of the melting process at the base of the permafrost, resulting in a decrease of the permafrost depth.“

*P15, L9-12: This is an important point but should be referenced by earlier studies which discuss how surface forcings penetrate deeper into soil and the time frame associated with the lag.

We have added a reference.

*P15, L15 and further: Although you are comparing your estimates at 50% frozen this

is probably not the case with the other studies, which assume 100% frozen and then this depends on what their freezing algorithm was, what temperature etc.

Please refer to our answer to reviewer 1 concerning the choice of the permafrost depth indicator. We do not wish to use the 100% frozen isoline as its position is highly sensitive to the choice of the solid-liquid interval width. A lot of studies use the 0°C isotherm as an indicator, which would allow to compare with our results (50% frozen $\sim$ -0.25°C).

*Almost all the figure and/or figure captions should be improved: Figure 1: Make sure all 17 polygons are represented and listed - my count was off.

This has been adapted.

*Figure 2: "mid-depth" porosity, is this half-way ?

Yes.

*Figure 4: Consider making y-axis scale same for both figures to more easily compare the two sites.

This has been done.

*Figure 6: X-axis "Distance" from what? Maybe put a little insert to illustrate the distance.

See Figure 1 for location of the profile.

*Figure 7: This figure caption does not explain what the percentile is of? The secondary x-axis should have a unit associated with it (% I think).

Percentiles do not have a unit. ‘Depth’ has been added to the caption.

*Figure 8: Both figures should align even on top of each other for more illustrative comparison. Permafrost thickness should be also illustrated with the curved, perhaps in a third figure below

We have aligned these figures. Figure 8 can be easily compared with figure 5. We think that adding more curves to these figures would compromise the readibility of these - already busy - figures.

Sincerely, J. Govaerts, K. Beerten, J. Ten Veen.

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/tc-2016-54/tc-2016-54-AC2-supplement.pdf

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