

Dear authors,

Thank you for your revised manuscript and your rebuttal letter. I have carefully read the revised version and find it suitable for publication after minor (but many) revisions as outlined below. Please implement these changes carefully and provide a justification where you disagree with my suggestions. To speed up the further process, please also provide a highlighted version of the revised manuscript so your changes can better be tracked.

Kind regards,
Stephan Gruber

Thank you, we will try to address your questions and suggestions in the following.

Title: Weichselian permafrost depth in the Netherlands: an uncertainty and sensitivity analysis (the Po Basin would also be lowland Europe...)

We agree. The title has been adapted.

MAJOR COMMENTS

Why is the “fully frozen front” the relevant metric (P6L13)? I have several issues with this: (a) no justification is given, (b) down to -40°C you will not find ‘fully’ frozen soil/rock and thus this only exists in your current parameterization – with all the inherent arbitrariness, (c) one would assume that the presence of any amount of ice would be relevant as this begins to affect hydraulic permeability and material structure. If you have a good reason to stick to ‘fully frozen’, please justify this well. If not, I suggest to us the definition of permafrost (<0°C) as this is (a) conservative and (b) provides a definite distinction of ground that can/cannot have ice. See next comment.

You give a valid permafrost definition, and at the same time you use a conflicting and arbitrary definition of -0.25°C as an indicator (P6L16, P13L8–10, P16L14, P17L31). This is arbitrary and confusing.

The ‘complete’ freezing of the soil near the radio-active waste repository would be the most penalising situation for the integrity of the engineered components of the system (concrete elements, bentonite seals, etc...). Therefore, the frozen front is the most relevant metric in this study. However, we agree that the choice for the -0.25 °C isotherm (or 50% frozen), which is based on the consideration to use the center temperature of the freezing interval, seems arbitrary when not familiar with the radio-active waste disposal concept. We therefore agree to use the 0°C isotherm as the permafrost indicator, which is in line with the given permafrost definition and makes this study easier to compare with similar permafrost modelling studies. All necessary figures were adapted and permafrost depth increased with

about 10 m due to the change of metric. The results and conclusions of the sensitivity analysis were not influenced by this.

Distinguish the description of material freezing behaviour and the parameterization used in your numerical scheme (P6L2/3 shows lack of understanding, as your liquidus/solidus parameterization of freezing may be interpreted of representing pore diameter and surface effects).

We have added the following: “As such, in this model representation, the freezing process is determined only by the change in temperature. The dependency of the freezing point of water on pressure, salinity and other possible influencing factors is not taken into account in the present calculations.”

P4L25–28: Please reformulate to clarify that (a) you describe the behavior of your parameterization (in reality there will be unfrozen water below you solidus) and (b) that this describes the behavior of water in a porous medium (a mixture of substances and not a pure material), correspondingly the term used should be ‘thaw’ rather than ‘melt’.

We have changed the text into: “During cooling, solidus is that temperature at which most of the pore water of the soil is frozen. Between the solidus and liquidus temperatures, there will be a mixture of solid and liquid water phases within the soil matrix. Just below the liquidus temperature, there will be mostly liquid water phases.”

All minor comments have been addressed in the marked version of the manuscript.

Please check you references for consistency with respect to capitalization and quotation marks.

This has been done.

Thank you,

Joan Govaerts

Koen Beerten

Johan Ten Veen