The Cryosphere Discussions

The Cryosphere Discuss., author comment AC2
https://doi.org/10.5194/tc-2022-134-AC2, 2022

Reply on RC2

Dotan Rotem et al.

Author comment on "Permafrost saline water and Early to mid-Holocene permafrost aggradation in Svalbard" by Dotan Rotem et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-134-AC2, 2022

Dear referee #2

Thank you very much for your helpful comments.

Please find below our replies to the comments (**in bold**)

Major Comments

- 1. The time step of 32,600 seconds is not 0.5 days as written in the text. Half a day is 43,200 seconds. Please check the simulations.

This is correct. The time steps were originally taken as 0.5 days but later on reduced to 32,600 sec (~9 hr) as to keep simulation stability.

We will correct, accordingly, in the revised text.

- I think the thermal conductivity is not correctly calculated and this can have a major impact on the results. In equation 2, the dry soil conductivity is used for the mineral fraction of the soil. However, the dry soil thermal conductivity is a bulk value. In this equation for saturated conditions, the "mineral thermal conductivity" should be used and this is typically around 3.0 W/(mK). Therefore, a value of 0.35 W/ (mK) is excessively low. Some nice examples of mineral conductivities are given in Overduin et al. (2019):

https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JC014675 The authors should check if similar errors were made for density and heat capacity. Further, there is an extra bracket on the right side of all three equations.

We used a thermal conductivity of 0.35 W/ (mK) for the dry sediment, following Wolfe, L. H., & Thieme, J. O. (1964) and Slusarchuk, W. A., & Watson, G. H.

(1975),□ □ referring to silt or fine grain dry soils. Following the reviewer's comment, we have re-run the model with 3.0 W/ (mK). In general, the obtained results predict faster freezing, which is compatible with the main conclusion of this paper. Our values of heat capacity and density are similar to those used in other works, including in the above reference (Overduin et al. (2019). In the revised version of the paper, we will also present diagrams with thermal conductivity of 3 W/ (mK).

- Because of the thermal conductivity error, I am skeptical of the permafrost aggradation rates. I am a little bit surprised that changing the porosity has such a small effect on the results, especially because the latent heat associated with such a change is significant. If the authors re-run the simulations with the correct thermal properties, I hypothesize that, the permafrost aggradation rates would be more divergent when considering different porosities.

We re-run the model with different porosities and with the suggested high conductivity values. As suggested by the reviewer the differences are notable. The results of the sensitivity tests will be presented and discussed in the revised version.

- The numerical model does not consider salt diffusion and therefore salts cannot migrate during the advance of the freezing front. While I do not expect the authors to incorporate salt diffusion into their model, I would appreciate some more discussion on this process. As the authors point out, ground freezing results in ionic exclusion, thereby increasing the porewater salt concentration. Consequently, this creates a porewater salt concentration gradient. Since the advance of the freezing front slows with time, the porewater salt concentration can be sufficiently strong at a particular depth to increase the porewater salinity and create a cryopeg or partially frozen conditions. How would the permafrost aggradation rates change if salt transport were included in the model? For coupled heat and salt diffusion models, consider the following paper: https://doi.org/10.1029/2018JF004823

Thanks for this comment. Basically, there is no indication of any cryopegs in this site, and the existence of an FSI (i.e. increase in salinity down core) suggest that salts did not migrate much away from the freezing front, at least within the depth we covered (12m). This is probably due to the fact that salt diffusion is 3 orders of magnitude lower than heat diffusion. Accordingly. at the beginning of Discussion chapter, we suggested that "permafrost pore space should hold a small fraction of residual brine solution, which contains most of the solutes originally dissolved in the bulk pore-space water". We will expand on this in the revised version. We note that we cannot exclude the existence of cryopegs in deeper permafrost, which could indeed affect our simulations for this part. We will note about this in the revised version.

- Please add a conceptual diagram of the Ghyben-Hertzberg approximation and include two panels (1 with permafrost and 1 without permafrost). This would really help the reader visualize how the fresh-saline interface is expected to look in unfrozen and frozen environments.

The Ghyben-Hertzberg approximation is partly presented in Figure 7, but is probably not clear enough. We will dedicate a figure to this in the revised version

- If available, could you please include ground temperature data with the geochemical ground ice data in Table 1? At the very least, were in-situ frozen and unfrozen conditions recorded during drilling? Please add this information.

Such data is not available, since Temperature cannot be reliably determined during drilling. We refer to Hanne's Christiansen data, which was taken down the valley, therefore not necessarily representing the site. We did record cores condition during drilling and it appears in the discussion. We will add it to table 1 in the revised version.

Minor Comments

We will follow these comments and correct accordingly in the revised version

Thank you again for your time and very instructive notes.

Dotan