Reply to Editor Comments

Dear Editors:

Thank you very much for your further guidance on our manuscript within your busy schedule, and we have revised the article in more detail based on your and the referee's comments.

In summary:

1) We explained the kinds of solutions used for the different experimental treatments.
2) We added a comparison with references recommended by referees.
3) We acknowledged the effect of the solution viscosities on the infiltration parameters.
4) We added the value of the permeability in Table 6.
5) We discussed the potential uncertainty in the Y-axis of Figure 6.

Below, please find a detailed set of responses to specific comments. We referred to the most related lines from the latest unmarked revision of the manuscript. If there are still anything else you feel needs to be revised, please feel free to contact us.

Comments from Referee #1:

Comments #4: How was the pre-freezing moisture content held consistent between samples, and after BF tests?

Comments #6: How was the pre-freeing water content controlled?

Response: The use of a spray bottle to add water in small quantities but several times, and the use of sensors to monitor the moisture values guarantee the uniformity of the moisture content of the soil columns and the relative consistency of the pre-freeze moisture between different columns. This part is shown in L136-140.

Comments #5: In unfrozen tension infiltrometer experiments, the soil moisture is assumed to be that imposed by the applied tension. If samples were frozen before infiltrometer experiments, then is it assumed that the applied tension then only affects the pores that are active during infiltration?

Response: We have acknowledged the relevant assumptions and limitations in the discussion section as suggested by the referee, which will make the theoretical support of the article more rigorous. As shown in L366-368.

Comments #10: L71-73: Zhao et al. (2013) did not introduce the 'impedance concept', it was proposed far earlier, at least as early as Jame and Norum (1980).

Response: We have added the reference suggested by the referee in the corresponding places. As shown in L74.

Relevant references

Jame, Y.-W., D.I. Norum. Heat and mass transfer in a freezing unsaturated porous medium[J]. Water Resources Research, 1980, 16(4):811 - 819.

Comments #13: L152: Authors should state clearly that pure water was used as the infiltration solution for the unfrozen experiments. Also were the samples gravity drained after the unfrozen test? Were the samples adjusted to ensure consistent pre-freezing soil moisture among samples?

Response: This was our oversight, there is really no clear statement in the previous manuscript. We have added a clear explanation in the test plan section, which can be seen in L170-172. In addition, Table 3 shows the physicochemical properties of two liquids, water (15℃) and ethylene glycol aqueous solution(-5℃and-10℃).

Comments #16: L322-341: This is fascinating, and in my opinion, is the most novel part of this study. But this is conjecture, and there are quantitative ways to examine soil structure before and after freezing, see for example Holten et al. (2018) and Ding et al. (2019), who actually apply geophysical imaging techniques to quantity pore structure in relation to frozen soil infiltration.

Response: References mentioned by the reviewers are added to the discussion section with appropriate comparative comments and can be seen in L404-411.

Comments #18: L368-372: Not sure I agree with this statement, as your data contradicts it, and at atmospheric pressure, air-filled macropores will conduct most water, regardless of antecedent moisture.

Response: The values here are calculated using Equation 6, as they are very small and close to the zero point of the unsaturated hydraulic conductivity variation curves in Figure 5. We gave a brief description in the Discussion section and acknowledged the effect of different fluid viscosities on the infiltration parameters, as can be seen in L393-394 and L398-401.

Comments from Referee #2:

Comments #1: My main concern about the manuscript regards how the results can be related to infiltration of water in soil, as the solution used here has different properties from water (e.g. viscosity). Are the presented values of estimated hydraulic conductivity for the glycol solution or for water? It would be most helpful to present values for water, or perhaps permeability values rather than hydraulic conductivity values.

Response: We added the value of permeability to Table 6 based on your and the referee's comments, but there is a slight difference between our calculated value and the one you gave, your value is about 1.08 times of our result. We have used the following formula to calculate the permeability, but we are not sure if the formula or other factors are responsible for these differences. If you find the error in it, please give us further guidance.

$$Permeability=\frac{K_{sat}\mu}{\rho g}$$

where K_{sat} is the saturated hydraulic conductivity, m/s; μ is the dynamic viscosity of the fluid, mPa·s;

ρ is the density of liquid, kg/m^3; g is the acceleration of gravity, 9.8N/kg.

Comments #12: L273: What is meant by “stable frozen”? Is all water/liquid turned to ice at this temperature?

Response: The stable frozen state usually indicates that no drastic changes in temperature and water content occur. It has been clarified in text, as shown in L290-291.

Comments: Check Y axis title Fig 6: is there any uncertainty related to these estimates?

Response: We are not quite sure what exactly this uncertainty means, so in the previous revision we just standardized the Y-axis of the internal expansion chart to scientific notation. For the Y-axis of Fig. 6, the uncertainty of N and θ_m values mainly comes from the soil pore radius r, and we expanded a related discussion, as seen in L427-431.