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Discussions
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Interactive comment on "Effects of multi-scale heterogeneity on the simulated evolution of ice-rich permafrost lowlands under a warming climate" *by* Jan Nitzbon et al.

Anonymous Referee #2

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Authors implement micro- and meso-scale spatial grid resolution in the 1D CryoGrid model to illustrate the spatial effect of microtopographic feature on the rate of permafrost thaw. Authors found that implementing higher spatial resolution in the model leads to "more realistic possibilities (L13)". Now sure what type of possibilities they have in mind? Improving spatial representation of the polygonal tundra in the ESM type models is important. However, the current version of the manuscript lacks clarity. I found it hard to follow and the central Figure 2 looks like an electrical circuit diagram. If the take-home message is that every ESM needs to have micro-, meso-scale permafrost tundra representation, then it needs to be clearly stated. Maybe including recommendations on how authors think that can be done easily, in their opinion, using

the current approach. Overall, this is a timely and important work that needs to be published. However, the description, terminology, and flow require more work. I have a hard time reading and understanding the concept laid in the paper. I understand that much of the tiling concept was introduced in previous work (Aas et al.). However, the recap could be extremely helpful in setting up the stage in this study. Also, talking about uncertainties between different tiling approaches might be useful too. For example, if we average the overall effect from individual polygons, it could have the same carbon footprint as representing the polygonal tundra heterogeneity in one tile. When could that be or not be true? The comments below illustrate the lack of my knowledge of the presented scaling method. I hope the authors would not be discouraged by my comments and try to help me better understand their work in the revised version of the manuscript.

Abstract Can be shortened and cleaned. There are too many we found..., also found..., for example..., our results suggest... It was really hard to wrap my head around what exactly was found and how that helps science, stakeholders, economy, etc.

L50. What is tile-based modeling approach? Need to define.

L77. "To quantify the sensitivity". I am not sure how the sensitivity was addressed?

L79. What type of sources of uncertainty? See my main comments. By making super refined models, we can introduce many small uncertainties which will superposition at the end. The question is, where is the golden ratio?

Table 1. should it be m2? Are we talking about the gridcell resolution?

Figure 1. Are you simulating the transect or an entire area? If you model an entire area, then how that area is going to look under different resolutions? In an ideal case, we should be able to take any area and then apply a deferent resolution to it (zooming in and out). The different surface features will be more/less pronounced based on

spatial resolution. Then we can model future changes under different resolutions and the difference between modeling results should tell us how fine we should go. This way sounds more straight forward to me...

L127 what is field capacity?

If I understand it correctly, the θ_i is initialized? I suggest to rename Δp to Δd_ice. Typically, p represent pressure. So, ice thickness is initialized too? Does the model start from the initialized ice thickness or there is a steady-state run? So, the second term in equation 2 should be less than or equal to 1? Otherwise subsidence could be greater than the ice thickness. Can that be the case? I did not understand the denominator. What is 1-phi_{nat} mean?

L149. Need a reference after "... hierarchical approach".

N^μ is that somewhat standard notation? I had a hard time following that notation and remembering what it means. Is there a way to change it or use some other more intuitive notation? For example, use 1m2 or 1km2 notations. What is the total area modeled? Is this modeling represent a transect or a 2d area?

Does homogeneous means that one tile represents the entire transect. If so, then it would be easier to say that 1 tile approach. What is the external reservoir? Is that water table depth?

Figure 2, I had a hard time to understand and follow.

L204 How many topological characteristics were used? Are these characteristics represent only magnitude of the lateral fluxes or something else too?

Table 3 what is 'not a null' over 'big sigma' columns represent? I like the results section and was able to make more sense of it. I think that discussing the geomorphological processes as well as figure 6 diversify the message: "the importance of the tile-approach adoption by the ESM type models." I guess, it is important to focus on that message instead of diving into the concepts and pathways of the polygonal tundra

geomorphological evolution.

For this type of paper, I would like to see a more in-depth mathematical analysis of the difference between different spatial resolutions as well as discussion of the corresponding uncertainties. I understand that this might lead to way too much work and may not be feasible in this paper. Then I suggest to exclude the ESM modeling discussion from the article and give it a different angle from the beginning. Consider bringing Figure 6 into the methods or introduction. Then it will setup the stage for the follow-up story.