

The Cryosphere Discuss., referee comment RC1
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Comment on tc-2021-207

Anonymous Referee #1

Referee comment on "The importance of freeze–thaw cycles for lateral tracer transport in ice-wedge polygons" by Elchin E. Jafarov et al., The Cryosphere Discuss.,
<https://doi.org/10.5194/tc-2021-207-RC1>, 2021

Jafarov et al. conduct a modeling study using ATS to assess the impact of freeze-thaw and freeze-up on lateral flow in high- and low-centered polygons. This study integrates a new modeling capability into ATS that enables tracking of non-reactive tracer movement due to advective transport. This study incorporates two transects (i.e., domains) representing high- and low-centered polygons and two freeze thaw scenarios – one scenario with seasonally dynamic freeze-thaw and one scenario with the active season only (i.e., excluding freeze-thaw and freeze-up) to assess lateral tracer movement over two years. This study confirmed field studies by Wales et al. (2020) that suggests that freeze-up has a large impact on tracer transport. Simulations show significant lateral transport within two thaw seasons and this transport was greater in scenarios with freeze-thaw. Results also showed that the impact of freeze-thaw was greater in low-centered polygons, as evidence by the increased difference in tracer transport between freeze-thaw enabled and disabled scenarios for low-centered polygons compared to high-centered polygons.

Overall, this is an interesting and important study and will be of interest to the readership of *The Cryosphere*. This study not only contributes important advances in cryohydrogeological modeling, but also provides important insights into lateral flow in ice-wedge polygons and potential carbon transport. The modeling setup and analyses are sound, and the results are clearly conveyed.

I have a few general and line specific comments articulated below:

General comments:

- The discussion section needs to be expanded and developed to include more

explanation and context to the points addressed. In select sections such as 4.3, the discussion reads more like a results section than a discussion of the findings, leaving the reader with questions such as: Why does freeze-up impact tracer transport? Why is it greater in some scenarios than others? What are the drivers and processes at play? Why does most of the tracer flux for low-centered polygons occur during the freeze-up period in low permeability scenarios? The results are interesting and important, but the manuscript lacks depth beyond results reporting. Addressing these questions in addition to other similar questions will greatly improve the manuscript and the impact of the paper.

- Similarly, the drivers of transport were not discussed in the manuscript. There is no text discussing hydraulic gradients and little with respect to thermal gradients. This is important when discussing lateral flow with time. How do the hydraulic gradients change with time? Between scenarios? How about the thermal gradients? I strongly addressing these questions, or thoroughly discussing drivers of flow in the text. Adding in even a few well-crafted and well-placed sentences discussing the processes influencing the results will significantly improve the manuscript and its impact.
- While a tracer is one way to track lateral flow of a non-reactive solute, DOC is reactive. Given the focus on and links to carbon transport made in the manuscript, I suggest adding text that addresses how DOC transport differs from tracer transport. Perhaps it is obvious, however, it is important to mention that DOC is (1) reactive, (2) can be entrapped in ice, and (3) impacted by local conditions. Please also add text as to how this may impact the results of this study.
- Please check the manuscript for typos. There are several instanced throughout the manuscript, some of which have been identified below.

Specific comments:

Line 26-27: Rephrase. Perhaps add 'on' after 'controls'.

Line 28: I suggest adding examples of transport conditions.

Line 45-55: This section is repetitive and seems to jump between sentences. I suggest reordering the text to incorporate the hypothesis in the first paragraph then what was done in the second to avoid repeating findings of Wales et al. (2020).

Line 51: add 'but' after the comma.

Line 61: Add an 's' to simulation.

Line 64: Add an 's' to implication.

Line 83: Please clarify the Q^c term and how it is determined.

Equation 4: Define ε .

116: Please add a reference for the domain specifications.

Line 199. Please add 'is' after 'and'.

Line 130. For clarity, this sentence could be rephrased to 'no-flow energy boundary conditions on the sides of the domain.'

Line 131: Please more thoroughly explain the 4 cm. Why at 4 cm? Is this a point or a line segment, and if so, from where to 4 cm? Would the seepage location impact the results?

Line 132: I believe 'drainage' should be 'drain'.

Line 137: I suggest adding 'started' after 'season'.

Line 142: Remove the second 'in'.

Line 145-150: Were diurnal temperature changes included?

Line 257: This sentence needs more detail. Impacts of what? "may be responsible..." for what? More text in this sentence will add clarity and make the point (and this section) clearer.

Figure 1: Please include units in the axis titles. Also, I suggest reassigning letters to the plots to match the rest of the figures (i.e., a,b,c,d rather than a,c,b,d). Additionally, it may help to find a way to indicate a dynamics permafrost boundary in b and d. The depiction as is was initially confusing.