The Cryosphere Discussions

The Cryosphere Discuss., referee comment RC2
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Comment on tc-2021-207

Anonymous Referee #2

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-RC2, 2021

The paper discusses the effect of freeze/thaw cycles on lateral transport of conservative solutes in polygonal tundra, and links this transport to soil carbon cycling. A new transport capability is incorporated into ATS, an existing hydrothermal model. By comparison to field data, the modelled cases indicate that lateral transport may be an important feature of dissolved carbon.

The paper is well structured, easy to follow and the modelling mostly appears scientifically sound and well performed.

Below, I first provide some more general comments, followed by minor or editorial comments.

Major comments:

- While the introduction nicely explains why lateral transport of carbon is important to understand and quantify, it remains somewhat unclear if the lateral transport in a single polygon is critical. That is, the paper could somewhat elaborate on what happens with dissolved carbon once it reaches the edge (trough) of a single polygon. If it is released immediately similarly to the carbon which is transported vertically, maybe the effect is minor. Also, it would be helpful if the authors could provide some more detail on in what form carbon is transported, and what its ultimate form is when released. Maybe by outlining the relevant reactions this would become clearer.

- In order to mimic the tracer experiment, the tracer source is placed on the surface of the polygon. I wonder if not a more realistic source, in order to ultimately understand DOC transport, would have been to distribute the source vertically within the active layer.
- The paper clearly demonstrates how the freeze/thaw cycle promotes lateral transport relative to the freeze/thaw disabled case. But is not this enhanced transport mainly a fact of assigning a zero permeability in the active layer for the freeze/thaw disabled case such that solute becomes immobilized for large parts of the year? That is, how does vertical transport compare between the two cases; is that also enhanced for the freeze/thaw enabled case?
- Concerning the governing equations (1)-(2) and equation (3), I note the following:
  - C_l should be mass fraction (rather than mass as stated)?
  - The units of the LHS of eq (1) and (2) are not the same (seem to differ by a length unit)
  - In eq (3), should not the RHS be divided by porosity in order to obtain the liquid velocity?
- Did Wales et al. (2020) observe the same pattern (differences) between the two consecutive years as in the numerical simulations? If not, please elaborate on the possible deviation.
- As a complement to Figures 3-6, I think it would be helpful to plot cumulative mass discharge as a function of time at the polygonal boundary (i.e., at 10 m distance from center). This would aid in understanding the temporal evolution.

Minor comments:

- Line 27: insert 'what' before 'controls'.
- Line 119: Should be 'equals'.
- Lines 137-138: Clarify when the tracer is applied; i.e., is it 20 days after the end of the first thaw season?
- Lines 145-146: Is the impermeable layer constant in space?
- Line 153: Specify if the suggested time period of several days to weeks is site-specific or a general statement.
- Line 211: How much is porosity reduced in this variant?
- Line 219: How much is permeability reduced in this variant?
- Lines 235-238: Did the modelling include unsaturated flow?
- Line 313: Superscript missing in 0°C.