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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Understanding the Relative Importance of Vertical and Horizontal Flow in Ice-Wedge Polygons" *by* Nathan A. Wales et al.

Anonymous Referee #2

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General comment:

The authors report on a bromide tracer experiment that took place in a single high-centered polygon and a single low-centered polygon in northern Alaska at the Barrow NGEE-Arctic site. The tracer was applied in 2015 and then measured through several sampling ports installed at different locations and depths across the polygon, including in adjacent troughs. The field conditions at the site are difficult and the thaw season is short; hence, the amount of data is sparse, as is the potential to conduct similar experiments across a larger number of polygons. The authors used a 1-D analytical solution to the convective-dispersion equation to estimate subsurface flow parameters,

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including vertical and lateral hydraulic conductivity (it appears that retardation factor was assumed based on a literature value). The comments below identify a number of areas that need further consideration. For example, the analytical solution assumes a point application, but the tracer in this case was applied to a large area; how should we interpret the boundary conditions used to determine lateral transport parameters? Also, the authors did not include any soil temperature in the manuscript, which would help identify freeze up and thaw, and the potential existence of ice lenses that would almost certainly impact the uniformity of vertical soil water flow. Without these data, the authors relied on conjecture to explain non-uniform transport behavior through the upper thawed soil. It is recommended that the authors include the time-series data on ice table depth, thus potentially helping here. Other comments are found below.

Specific comments – comments called out by x/y, where x is page and y is line number

3/8 – authors should clarify here that only one high-centered polygon and one low-centered polygon were analyzed. As written, it appears that multiple polygons of both types were studied.

4/15 – what was the total area into which bromide tracer was applied?

5/8 – swap Figs. 4a and 4b to follow the order of call outs. Also, the description of the field setup using the silicon sheets doesn't appear on the subfigures. Suggest showing more detail in the schematic, so that the reader can note the silicon sheet, and that "surface" equals ground surface in current Fig. 4b.

5/26 – does the HCP have rims, as indicated in the sentence?

6/18 – given that ponded water apparently existed in the LCP during tracer application, any information on soil water content to confirm that the thawed soil was fully wetted?

6/30 – any soil temperature here or elsewhere at BEO that might be applicable here? Also, it would be helpful for the authors to add a table (here or SI) that lists the frost table depth with time, especially given the importance to lateral transport and heterogeneity

of the frost table depth.

Figure 5 – suggest adding calendar date to either the x-axis or the caption, so that the reader can understand year-to-year variability of onset of thaw

8/10 – van Genuchten and Alves (1982) solution assumes 1D transport, or in the context of this experiment, a point application of tracer. How does the broad area of application square with this assumption? Was it only used to estimate velocities during that segment of the flowpath, and then a second calculation for estimating horizontal flow? How is lateral distance determined for those sampling clusters outside of the application area? Also note that the van Genuchten and Alves reference on 24/33 is incomplete.

9/5 – check table 2. As presented, neither background concentrations nor tracer injection data are included

9/9 – the retardation factor for Korom's experiment were for sediment with a pH of between 5.1 and 5.7. According to Goldberg and Kabengi (2010, doi:10.2136/vzj2010.0028), retardation of bromide is very pH dependent. In some cases, bromide transport in soil with can lead to retardation factors significantly less than one (see for example Hills et al., 1991, WRR, paper 91WR015). How do the soil conditions at the Barrow site compare with those from Korom? Are the data robust enough to estimate R either through parameter estimation or other means? Given how R scales the tracer velocity, so more thought on this issue is warranted.

9/23 – any particular reason why sampling and analyses occurred for only two years, when it became clear that tracer recovery would be so low?

9/25 – here and elsewhere, it is suggested that the authors refer to tracer application in the polygon interior, rather than application in the polygon center. Indeed, most of the interior of the polygon received tracer, rather than a point application.

10/8 – if I understand the narrative correctly, the polygon was represented as an ide-

alized vertical cylinder, and the flux was estimated through the bottom of the cylinder based on measurements from the rhizon nests, is that correct? Was the flux then used as initial conditions for the lateral flow the nests outside of the cylinder?

11 (general) – the authors seem to bounce from LCP and HCP results, first referring to water levels, then to delta H values for both. It would be easier to discuss LCP first, then HCP second

Figure 8 – Fig. 8a shows location of GPR measurements and results, but not frost table slope, and Fig. 8b shows frost table slope but not GPR measurements. Could both results be shown for both polygons?

14/2 – replace “Surface” with “Trough”

14/5 – similar to the comment above, any soil temperature data that could help interpret these results in successive years? The reduced concentration from the end of 2015 to the beginning of 2016 is puzzling and potentially indicates transport even though water appeared frozen.

15/22 – are the authors stating that tracer recovery of 4.80% is actually a high estimate?

15/25 – when authors refer to polygon ‘center,’ is this really the polygon ‘interior?’

16/21 – authors are using either preferential flowpaths or heterogeneity of subsurface media as possible reasons for non-uniform vertical flow, or bypass flow around shallow samplers. A third explanation here is that the soil has undergone partial melting or partial freezing, reducing liquid water-filled transport pathways, and facilitating transport through specific pathways. This might also explain why tracers are changing concentration so drastically between thaw seasons.

Figure 12 – though the figures are interesting, there’s not enough explanation behind them to know whether the conditions represented by these images are the same as those observed at the traced polygons. It is suggested that the authors either more

closely tie the images from Romanovsky to the site being reported on here, or consider removing the figures altogether.

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