Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2020-30-AC2, 2020

Hydrology and Earth System Sciences
Open Access
Discussions

Interactive comment on "A Field Evidence Model: How to Predict Transport in a Heterogeneous Aquifers at Low Investigation Level?" *by* Alraune Zech et al.

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Received and published: 18 May 2020

First, we want to thank the referee for his positive evaluation of our work. We appreciate the time and effort he put into reviewing the manuscript. The paper will benefit from revising it according to the comments.

This response will address all general questions raised. Consequential text modifications in the manuscript will be outlined in the next step of the reviewing process (not intended in this step) along with correction of typos etc. Referee's points referring to the same topic, are bundled giving a deviation of the original order at times.

- Eq. 1 will be adapted to 3D.
- The boundary and contrast between the areas of distinct hydraulic properties: (raised in relation to Figure 1, Ls 155, 248, and 250):
  - The position of the boundary between blocks: Studying Figure 1 (left) shows that 20m down stream of the source (black dot) the head pattern changes abruptly. Along the orange line in the left figure there are 4 head isolines whereas along the green line of 40m length only one. This is a strong indication for a change of mean hydraulic conductivity. Thus, we chose this position as location for the interface of distinct material blocks. Figure 1 (right) indicates the vertical cross section where the choice of the coordinate system is along the one outline in the left figure. Part of this explanation will be integrated to the manuscript to clarify the choice and figures.
  - evidence of these large differences, e.g. by two large scale pumping tests as discussed in e.g. Boggs et al., 1992. We will add the reference at that location and elaborate.
- (L. 174ff) Inclusion topology: We will revise the paragraphs on the inclusion topology according to the points raised by the reviewer, explaining the choice of Ih and Iv and elaborate on what we mean with "expert knowledge".
- (L 189) We can extend the text to give a definition of ergodicity: Intuitively speaking, the ergodic hypothesis for a system implies that all states of the ensemble are available in each realization [Dagan, 1989]. A figurative description in the context of transport is, that the plume sampled sufficient heterogeneity over its travel distance to be representative for the average behavior of the heterogeneous material structure. The value of 10-100 characteristics lengths follows from stochastic arguments of the sample size [Dagan, 1988,1989].
- (L. 272) Inclusion's structure and choice of horizontal inclusion length Ih:

- The parameter I_h is the most difficult to extract from data, generally due to the very limited amount of information on horizontal structures and connectivity. Thus, a pragmatic, but also stochastic meaningful approach is necessary. We decided to combine estimates from the data (the range of $I_h \in [5m, 20m]$ deduced from vertical inclusion length and the anisotropy rate), with the approach of parametric uncertainty: instead of using only one value out of the range, we allow for 3 different: 5m, 10m and 20m. The different inclusion length produce distinct effects on connected pathways and thus on the mass distribution. In the combined ensemble the character of each inclusion length is thus integrated.
- The ensemble thus consists of 3* 200 realization of each inclusion length.
- The formulation heuristic approach might be misleading. We will consider reformulating it. We will also expand the paragraph providing the additional information outlined above.

• (L 275): We used 600 realizations to assure that the number is sufficiently large to ensure ensemble convergence. As stated in the manuscript, we found in preliminary convergence tests, that 200 realizations are sufficient to reproduce ensembles averages. Given the combination of different inclusion length (previous comment), we combined 3*200 realizations for the general ensemble representing model structure A+B.

• (L. 294): Dimensionality of the model: The model is indeed 2D not 3D.

- In preparation of the model, we also performed 3D simulations (for a reduced set of realization due to computational effort) and found almost no differences to 2D results. This can be explained by the conceptualization of the heterogeneous binary structure. So addressing the question "You expect differences in the results?" - Almost non; nor in the flow pattern and hence in the mass distribution pattern. Thus, we decided to stick with 2D.

- Extending the binary structure in the y-direction will be like combining many copies of the 2D cross section perpendicular to flow. This will cause no real change in the flow pattern. The inclusion length in y-direction is the same as in x-direction (as long as there is no indication of horizontal anisotropy). Thus, the binary structure does not change over several meters in y-direction. Inclusions extend along and perpendicular to the flow direction, giving the flow no reason to deviate from the main flow path. In this sense, the flow pattern is hardly impacted by the additional degree of freedom and the mean flow velocity is almost identical in 2D and 3D.
- We are aware that this is in contrast to log-normal random fields, where flow in uniform fields shows higher effective K values in 3D than 2D. The difference is: in log-normal fields, K-values change gradually in all directions. Thus, adding a 3rd dimension perpendicular to the main flow direction allows to circumvent areas of low conductivity and thus increases the effective mean flow velocity. In the binary material, there are no gradual changes. A layer of low conductivity in horizontal direction extends in both, x- and y-direction, being an obstacle for the flow and not allowing for "flowing around" in y-direction.
- The very light differences between 2D and 3D we observed, we refer to a slight increase of mean flow velocity due to a higher connectivity of inclusion in 3D. However, this is only relevant over a large domain and does hardly impact the local flow pattern in the area where transport takes place.
- A 3D model would be a more realistic setup, but in this particular application it does not change the results due to the conceptualization of the binary model. The additional degree of freedom does not impact the flow pattern. Thus, a 3D model increases effort but brings no benefits. In contrary, setting up Monte Carlo simulation with a 3D model would keep practitioners from adapting our approach for other field situation. However, we agree that for other conceptualization of heterogeneous hydraulic conductivity a 3D model

setup is preferable.

- (L. 296): Solute injection follows the experimental description in Boggs et al., 1992. It is a flux related injection being the realistic representation of natural conditions. Thus the local distribution of tracer depends o the local heterogeneity.
- (Figure 6): We will add a legend to Figure 6.
- (L. 396) We will adapt the conclusions accordingly.

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