November 6, 2018

We thank Reviewer #1 for the valuable comments to our manuscript. The following is the list of the responses to the comments proposed by Reviewer #1.

1)
3.1 Transport model verification by using HYDROGEOCHEM model
'The boundary conditions along the boundaries parallel to the flow direction are specified to be no-flow boundary conditions, except for the cross-shaped fracture network case, where a slightly upward flow along the vertical fracture is introduced'
Please explain better the upward flow. Is it a constant head value of 9 m as shown by the figure?

Response:
Yes, the upward flow was created by a constant head assigned on the top boundary of the vertical fracture.
We will add detailed description for the B.C. of the case with cross-shaped fracture network. Additionally, the Figures 3c and d will be modified to make the concept clear.
Thanks for the suggestion.

2)
3.2 Transport model verification by using analytical solution
On the basis of which criteria did you choose the dispersivities in the HYDROGEOCHEM model and the analytical solution?

Response:
We proposed that the fractures have rough surfaces with numerous contact points and fractures consist of the void space enclosed between two impermeable surfaces, which in a topological sense constitutes a two-dimensional porous medium. Therefore, the concept of porous fracture plates was employed in this study to formulate three-dimensional DFNs (Pruess and Tsang, 1990). Such porous fracture plates enable the use of HYDROGEOCHEM model and the analytical model for validations
The isotropic dispersivity used for the test cases was 0.1m. This value was determined based on the study of scale-dependent dispersivity proposed by

Gelhar et. al.(1992). In our study, the interested scale is approximately on the order of 1m. Therefore, in our validation cases with the domain sizes of 2m, we use 0.1m to be the isotropic dispersivity for the transport simulation. Thank you for the comment. We will add the detailed information in the revised manuscript.

References:
Pruess, K., Tsang, Y.W., 1990. On two-phase relative permeability and capillary pressure of rough-walled rock fractures. Water Resour. Res., 26, 1915–1926.
Gelhar, L.W., Wetly, C., Rehfeldt, K.R., 1992. A critical review of data on field-scale dispersion in aquifers. Water Resour. Res., 28(7), 1955-1974.

3)
4.1 Transport model verification
'The longitudinal dispersion is relatively obvious as compared to the transverse dispersion'. Explain this sentence.

Response:
Thank you for the comment. We will modify the discussion in the manuscript. In the comparison cases, the isotropic dispersivity was assigned for the simulation. Based on the x-direction uniform flow applied to the model, the effect of directional dispersion on the transport should be the same. The dispersion coefficient for x- and y-directions are:

$$\boldsymbol{D}_{xx}(\mathbf{x}) = \alpha_L(\mathbf{x})\frac{v_x v_x}{\bar{v}} + \boldsymbol{D}_o(\mathbf{x}), \quad (1)$$

and

$$\boldsymbol{D}_{yy}(\mathbf{x}) = \alpha_T(\mathbf{x})\frac{v_x v_x}{\bar{v}} + \boldsymbol{D}_o(\mathbf{x}), \quad (2)$$

where $a_L(\mathbf{x})$ is the longitudinal dispersivity in the principal flow direction. $a_T(\mathbf{x})$ represents the transverse dispersivity, which is perpendicular to the longitudinal dispersivity. Notations $v_x = v_x(\mathbf{x})$ and $v_y = v_y(\mathbf{x})$ are the seepage velocities in different directions in the porous fractures and $\bar{v}$ represents the magnitude of the seepage velocity. Notation $D_o(\mathbf{x})$ is the effective molecular diffusion coefficient.
In the test example, the contribution from the advective transport is mainly from the seepage velocity in the x-direction. We will modify the discussion

and revise the equations to make the presentation clear.

4)

Figure 9

Please define in a careful way the parameters P_{21} and P_{32} as well as P^e_{21} P^e_{32} P^t_{32} as the notations are quite misleading.

How did you calculate those parameters and do they differentiate among each other? And also better interpret the graph on the basis of those parameters and others such as fracture hydraulic conductivity and equivalent hydraulic conductivity. The discussion of graph 9d is not clear. Please provide a more accurate interpretation of the results.

Response:

Thanks for the comments. The definitions for different fracture intensities will be defined clearly in the revised manuscript. Additionally, the calculations of these values will be presented with details.

In this study the parameters P_{21} and P_{32} are the length of fracture traces per unit area (2D domain) and the area of fractures per unit volume (3D domain), respectively. We add a superscription "e" to indicate the intensity of effective fractures. The effective fractures are those that neglect isolated fractures in a rock. The superscription "t" represents the total fracture intensity for a rock. The concept of the equivalent hydraulic conductivity is to support the discussion of up-scaling issue. The detailed information and discussion will be provided in the revised manuscript.

5)

5 Conclusions

The Conclusion is a mere summary of the obtained results. Rewrite the conclusion adding a more extensive interpretation and discussion of the results, including clarifications on the novelty of the proposed approach and how it would provide a benefit to the scientific community.

Response:

Thanks for the comments. Yes, there are novelty of the proposed approach and benefits to the scientific community.

Numerical solutions to the ADE based on the Eulerian approach have not been widely implemented to DFN. This is because of computational issues such as numerical dispersion and convergence in the model for complex fracture connections. With the developed model, we also found interesting results that can contribute to the research communities of flow and transport in fractured rocks. We will follow the suggestions to rewire the conclusion.