EGU21-12255
https://doi.org/10.5194/egusphere-egu21-12255
EGU General Assembly 2021

Flow partitioning in partially saturated fracture networks: Relation between dispersive properties and internal fracture geometry

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Modeling of of infiltration and recharge dynamics in fractured-porous aquifers remain an extremely challenging task due to the formation of preferential pathways along fracture networks and hence deviation from classical diffuse Darcy-type percolation patterns. In contrast to soil systems the vadose zone of consolidated rock systems often reaches depths of several tens to hundreds of meters which limits the accessibility and complicates the application of moisture measurement techniques. Under partially-saturated conditions flow through percolating fracture networks contribute to the fastest spectrum of infiltration velocities. At fracture intersections flow is often fragmented into a vertical and horizontal component which controls the dispersive properties of the infiltrating fluid front. As hydraulic information in consolidated aquifers is often only available at boreholes or springs, we explore how internal fracture network geometries can potentially be reconstructed from external boundary information, e.g., the dispersive properties of discharge (groundwater level fluctuations). In order to relate boundary information, e.g. discharge measured at the water table within boreholes, to internal properties such as geometry of the fracture network and fluid-solid interaction properties we derive an approximate analytical solution for flow through a cascade of simple fracture intersections with the help of parallalized smoothed particle hydrodynamics simulations [1]. Via linear response theory we derive expressions for the non-dimensional bulk flow velocities and dispersion coefficient to characterize the fracture network in terms in the dimensionless time scales of the vertical and horizontal fracture components. We demonstrate that the dispersion coefficient converges towards a universal value for a realistic range of fluid and solid properties and recover a characteristics Washburn-type scaling for the dimensionless velocity.

[1] Kordilla, J., Tartakovsky, A. M. and Dentz, M. (2020): Numerical and analytical modeling of flow partitioning in partially saturated fracture networks, Earth and Space Science Open Archive, pp. 44, doi:10.1002/essoar.10504345.1