Geophysical Research Abstracts
Vol. 16, EGU2014-10552, 2014
EGU General Assembly 2014

A single expression for solute and heat dispersion in homogeneous porous media

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A variety of expressions have been proposed for dispersion in homogeneous porous media. These expressions are either for heat (thermal) or solute dispersion, and often only valid for a limited range of flow rates, typically expressed in terms of the Péclet number. We present a single, universal expression for both the heat and solute dispersion coefficient (both transverse and longitudinal) in homogeneous porous media, valid over a wide range of Péclet numbers as long as flow is laminar.

The expression covers the complex intermediate regime between diffusion and advection controlled dispersion, where dispersion increases non-linearly with flow velocity. Using numerical simulations of pore channel networks, we show that that the intermediate regime can be regarded as a phase transition between random, diffusive transport at low flow velocity and ordered transport controlled by the geometry of the pore space at high flow velocities. This phase transition explains the first-order behavior in the intermediate regime. A new quantifier, the ratio of the amount of solute in dominantly advective versus dominantly diffusive pore channels, plays the role of "order parameter" of this phase transition.

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