Geophysical Research Abstracts
Vol. 16, EGU2014-1667, 2014
EGU General Assembly 2014

Origins of Anomalous Transport in Heterogeneous Media: Structural and Dynamic Controls

Yaniv Edery (1), Alberto Guadagnini (2), Harvey Scher (1), and Brian Berkowitz (1)

(1) Department of Earth and Planetary Sciences, Weizmann Institute of Science, Rehovot, Israel, (2) Dipartimento di Ingegneria Civile e Ambientale (DICA), Politecnico di Milano, Milano, Italy

Anomalous (or "non-Fickian") transport is ubiquitous in the context of tracer migration in geological formations. We quantitatively identify the origin of anomalous transport in a representative model of a heterogeneous porous medium under uniform (in the mean) flow conditions; we focus on anomalous transport which arises in the complex flow patterns of lognormally distributed hydraulic conductivity (K) fields, with several decades of K values. Transport in the domains is determined by a particle tracking technique and characterized by breakthrough curves (BTCs). The BTC averaged over multiple realizations demonstrates anomalous transport in all cases, which is accounted for entirely by a power-law distribution $\sim t^{-1-\beta}$ of local transition times, contained in the probability density function $\psi(t)$ of transition times, using the framework of a continuous time random walk (CTRW). A unique feature of our analysis is the derivation of $\psi(t)$ as a function of parameters quantifying the heterogeneity of the domain. In this context, we first establish the dominance of preferential pathways across each domain, and characterize the statistics of these pathways by forming a particle-visitation weighted histogram $\mathcal{H}_w(K)$. By converting the ln(K) dependence of $\mathcal{H}_w(K)$ into time, we demonstrate the equivalence of $\mathcal{H}_w(K)$ and $\psi(t)$, and delineate the region of $\mathcal{H}_w(K)$ that forms the power law of $\psi(t)$. This thus defines the origin of anomalous transport. Analysis of the preferential pathways clearly demonstrates the limitations of critical path analysis and percolation theory as a basis for determining the origin of anomalous transport. Furthermore, we derive an expression defining the power law exponent β in terms of the $\mathcal{H}_w(K)$ parameters. The equivalence between $\mathcal{H}_w(K)$ and $\psi(t)$ is a remarkable result, particularly given the nature of the K heterogeneity, the complexity of the flow field within each realization, and the statistics of the particle transitions.