Geophysical Research Abstracts
Vol. 12, EGU2010-3305, 2010
EGU General Assembly 2010

Effects of Physical and Chemical Heterogeneity on non-Fickian Transport

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A key problem in subsurface hydrology centers on modelling the physics of chemical transport in geological media, accounting for heterogeneity of physical properties (e.g., hydraulic conductivity, porosity) and/or of chemical properties (e.g., adsorption, desorption). Natural porous and fractured geological formations contain multi-scale physicochemical heterogeneities, and small-scale variability affects chemical plume migration patterns at much larger scales. The continuous time random walk (CTRW) framework provides an effective means to quantify this transport, allowing for the effects of both physical and chemical heterogeneities over a broad range of temporal and spatial scales. We first examine different types of hydraulic conductivity fields to ascertain the basic structural features that dominate the transport behavior. We contrast two approaches to the analysis, within the framework of the CTRW, to probe how different types of correlation can affect the larger-scale transport behavior. We demonstrate that different kinds of relatively small-scale features do not necessarily lead to distinct large-scale transport patterns. We then consider laboratory experiments involving transport of conservative and sorbing chemicals in porous media with different kinds of physical and chemical heterogeneity. We quantify the resulting non-Fickian transport behaviors using CTRW, demonstrating the effects of multiple scale physical heterogeneities on tailing patterns, and contrasting the parameter values that describe transport of conservative and sorbing species within the same domain. Our analyses further confirm the relevance and applicability of CTRW theory to a wide variety of laboratory- and field-scale observations, and numerical simulations.