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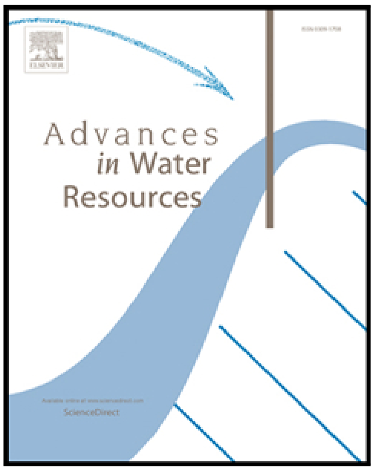

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Relating Recent Random Walk Models with Classical Perturbation Theory for Dispersion Predictions in the Heterogeneous Porous Subsurface

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Abstract

Recently developed stochastic macro-dispersion models enable computationally inexpensive flow and transport predictions for highly heterogeneous formations with statistically non-stationary conductivity and flow statistics. So far, the random processes at the heart of these models have been calibrated numerically based on velocity statistics from Monte Carlo simulation studies. In this work, we provide a more rigorous foundation to some of these models by analytically relating the process definition to given velocity statistics from classical first-order perturbation expansions.

Keywords: macro dispersion, PMVP model, random walk, perturbation expansion, Fokker–Planck equation

1. Introduction

The spreading of tracers in subsurface aquifers is typically dominated by velocity variations induced by the heterogeneity of the hydraulic conductivity, which is quantified by the log-conductivity variance σ_Y^2. This process is referred to as macro-dispersion [1, equation (5.1.10)]. Over the past few years, a number of publications have dealt with the formulation of effective Lagrangian transport models that enable the numerical prediction of subsurface dispersion [2–8]. At the heart of these transport models are different kinds of random walks that operate in velocity space. Earlier work [e.g., 9, 10] has focused on random walk models in physical space to account for pore-scale dispersion. This numerical treatment of pore-scale dispersion is attractive as it eliminates numerical diffusion, which is a problem in conventional schemes given the high Péclet numbers that arise in applications [11, section 10.5.2]. For the formulation of these models, the concentration evolution or advection–dispersion equation was rewritten as a Fokker–Planck (FP) equation [9, section 2] including a dispersion tensor

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