Inverse Stochastic Moment Analysis of Transient Flow in Randomly Heterogeneous Media

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Authors	Malama, B*, Dept. of Hydrology and Water Resources, University of Arizona, Tucson, AZ 85721 Neuman, S P, Dept. of Hydrology and Water Resources, University of Arizona, Tucson, AZ 85721
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Abstract

Nonlocal stochastic moment equations have been used successfully to analyze transient flow in randomly heterogeneous media conditional on measured values of medium properties. We present a geostatistical inverse algorithm that makes it possible to further condition such analyses on measured values of state variables, notably hydraulic head and flux. Our approach is based on Laplace-transformed recursive finite-element approximations of exact nonlocal first (mean) and second (variance-covariance) conditional moment equations and numerical inversion of their solution. Hydraulic conductivity (or transmissivity) is parameterized geostatistically based on measured values at discrete locations (if available) and unknown values at discrete "pilot points." Prior estimates of these unknown pilot point values are obtained (optionally, subject to the availability of sufficient measured values) by universal kriging. Posterior parameter estimates at pilot points and (optionally) at measurement points (thereby accounting for measurement errors) are obtained by calibrating the conditional mean flow equations against measured values of head and/or flux. The parameters are projected onto a computational grid via universal kriging. Maximum likelihood calibration allows one to estimate not only hydraulic but also (optionally) unknown variogram parameters with or without prior information about the former. The approach yields covariance matrices for parameter estimation as well as head and flux prediction errors, the latter being obtained a posteriori from recursive finite element approximations of the second conditional moment equations. Preliminary results are given for transient flow in a bounded two-dimensional domain.

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