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Stochastic characterization of the Montalto Uffugo research site (Italy) by geostatistical inversion of moment equations of groundwater flow

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We assess the applicability and performance of a methodology of inverting stochastic mean groundwater flow equations to characterize the spatial variability of (natural) log-transmissivity (Y) of a heterogeneous aquifer. The methodology, originally proposed by (Hernandez et al., 2003) and (Hernandez et al., 2006), relies on a nonlinear geostatistical inverse algorithm for recursive approximations of steady-state (ensemble) mean groundwater flow that allows estimating jointly the spatial variability of Y, the underlying variogram parameters, and the variance–covariance of the estimates. Estimates of prediction errors of hydraulic heads and fluxes are then calculated a posteriori, upon solving equations satisfied by the corresponding covariances. Here, we extend the methodology to quasi-steady state flow conditions and present its first field application by using information collected during a pumping test performed at the Montalto Uffugo research site (Italy). Log-transmissivity is parameterized geostatistically on the basis of an available measured value and a set of unknown values at discrete pilot points. Best estimates of Y at the measurement location and at the pilot points are obtained by a maximum likelihood fit of computed and measured heads. These posterior estimates are then projected onto the computational grid by kriging. Information on head drawdowns is provided through self-potential signals recorded by 47 surface electrodes during the test. The maximum likelihood-based objective function includes a regularization term reflecting prior information about Y. The relative weight assigned to this term is evaluated separately from other model parameters to avoid bias and instability. We explore the effectiveness of both a zero- and a second-order closure of the mean flow equation at providing a proper geostatistical characterization of the log-transmissivity field. The parameters of the variogram of Y are estimated a posteriori using formal model selection criteria. The adoption of a second-order mean flow model renders the sharpest definition of the regularization term and of the Y variogram parameters.