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Geostatistical inversion of moment eqations of groundwater flow at the Montalto Uffugo reasearch site (Italy)

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We present the application of a methodology of inverting stochastic mean groundwater flow equations to characterize the spatial variability of (natural) log-transmissivity of the Montalto Uffugo research site (Italy). The methodology has been originally proposed by Hernandez et al. [2003, 2006]. It relies on a nonlinear geostatistical inverse algorithm for steady-state groundwater flow that allows estimating jointly the spatial variability of log-transmissivity, the underlying variogram and its parameters, and the variance-covariance of the estimates. Exact mean flow equations are rendered workable by means of a suitable second-order approximation (in terms of a small parameter, representing the standard deviation of the underlying random log-transmissivities). A unique feature of the method is its capability of providing estimates of prediction errors of hydraulic heads and fluxes, which are calculated a posteriori, upon solving corresponding moment equations. Prior estimates of the transmissivity variogram and its associated parameters at the test site are obtained on the basis of available electrical resistivity data. Transmissivity is parameterized geostatistically on the basis of an available measured value and a set of unknown values at discrete pilot points. While prior pilot point values are obtained by generalized kriging, posterior estimates at pilot points are obtained by calibrating mean flow against late-time values of hydraulic head collected during a pumping test. Information on hydraulic heads is obtained on the basis of self-potential signals recorded by 47 surface electrodes during the test. We explore the effectiveness of both a second-order and a lower-order closure of the mean flow equation at capturing the parameters of the estimated log-transmissivity variogram. The latter are estimated a posteriori using formal model selection criteria. Our results highlight that assimilating hydrogeophysical data within a second-order model for mean hydraulic heads renders the sharpest definition of the key geostatistical parameters describing spatial variability of log-transmissivity.