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A comparison of seven inverse methods for modeling groundwater flow in mildly to strongly heterogeneous aquifers

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While several inverse modeling methods for groundwater flow have been developed during the last decades, hardly any comparisons among them have been published. We present a comparison of the performance of seven inverse methods, the Regularized Pilot Points Method (both in its classical estimation (RPPM-CE) and Monte Carlo (MC) simulation (RPPM-CS) variants), the Monte-Carlo variant of the Representer Method (RM), the Sequential-Self Calibration method (SSC), the Zonation Method (ZM), the Moment Equations Method (MEM) and a recently developed Semi-Analytical Method (SAM).

The aforementioned methods are applied to a two-dimensional synthetic set-up, depicting the steady-state groundwater flow around an extraction well in the presence of distributed recharge. Their relative performances were assessed in terms of characterization of (a) the log-transmissivity field, (b) the hydraulic head distribution and (c) the well catchment delineation with respect to the reference scenario. Simulations were performed for a mildly and strongly heterogeneous transmissivity field. Adopted comparison measures include the absolute mean error, the root mean square error and the average ensemble standard deviation (whenever a method allows evaluating it) of the log-transmissivity and hydraulic head distributions. In addition, the estimated median and reference well catchments were compared and the uncertainty associated with the estimated catchment was evaluated. We found that the MC-based methods (RPPM-CS, RM and SSC) yield very similar results in all tested scenarios, despite they use different parameterization schemes and different objective functions. The linear correlation coefficient between the estimates obtained by the different MC methods increases with the number of stochastic realizations adopted and attains values up to 0.99 for 500 stochastic realisations. For the mildly heterogeneous case, the other inverse methods (i.e., non MC) yielded results which were consistent with those obtained by the MC-based inverse models. The non-MC methods were negatively affected by the strong heterogeneity. Nevertheless, they always displayed a good performance and the differences between all methods were not very large.