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Optimization of Pilot Point Locations: an efficient and geostatistical perspective

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The pilot point method is a wide-spread method for calibrating ensembles of heterogeneous aquifer models on available field data such as hydraulic heads. The pilot points are virtual measurements of conductivity, introduced as localized carriers of information in the inverse procedure. For each heterogeneous aquifer realization, the pilot point values are calibrated until all calibration data are honored. Adequate placement and numbers of pilot points are crucial both for accurate representation of heterogeneity and to keep the computational costs of calibration at an acceptable level. Current placement methods for pilot points either rely solely on the expertise of the modeler, or they involve computationally costly sensitivity analyses. None of the existing placement methods directly addressed the geostatistical character of the placement and calibration problem.

This study presents a new method for optimal selection of pilot point locations. We combine ideas from Ensemble Kalman Filtering and geostatistical optimal design with straightforward optimization. In a first step, we emulate the pilot point method with a modified Ensemble Kalman Filter for parameter estimation at drastically reduced computational costs. This avoids the costly evaluation of sensitivity coefficients often used for optimal placement of pilot points. Second, we define task-driven objective functions for the optimal placement of pilot points, based on ideas from geostatistical optimal design of experiments. These objective functions can be evaluated at speed, without carrying out the actual calibration process, requiring nothing else but ensemble covariances that are available from step one. By formal optimization, we can find pilot point placement schemes that are optimal in representing the data for the task-at-hand with minimal numbers of pilot points.

In small synthetic test applications, we demonstrate the promising computational performance and the geostatistically logical choice of pilot point locations. In comparison with a classical regularly spaced pilot point grid, we achieved an equally good calibration result with a drastically smaller number of pilot points (only 5%), promising a much faster performance of the pilot point method itself.