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Minimization of required model runs in the Random Mixing approach to inverse groundwater flow and transport modeling

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Most geostatistical inverse groundwater flow and transport modelling approaches utilize a numerical solver to minimize the discrepancy between observed and simulated hydraulic heads and/or hydraulic concentration values. The optimization procedure often requires many model runs, which for complex models lead to long run times.
Random Mixing is a promising new geostatistical technique for inverse modelling. The method is an extension of the gradual deformation approach. It works by finding a field which preserves the covariance structure and maintains observed hydraulic conductivities. This field is perturbed by mixing it with new fields that fulfill the homogeneous conditions. This mixing is expressed as an optimization problem which aims to minimize the difference between the observed and simulated hydraulic heads and/or concentration values. To preserve the spatial structure, the mixing weights must lie on the unit hyper-sphere.
We present a modification to the Random Mixing algorithm which significantly reduces the number of model runs required. The approach involves taking n equally spaced points on the unit circle as weights for mixing conditional random fields. Each of these mixtures provides a solution to the forward model at the conditioning locations. For each of the locations the solutions are then interpolated around the circle to provide solutions for additional mixing weights at very low computational cost. The interpolated solutions are used to search for a mixture which maximally reduces the objective function. This is in contrast to other approaches which evaluate the objective function for the n mixtures and then interpolate the obtained values. Keeping the mixture on the unit circle makes it easy to generate equidistant sampling points in the space; however, this means that only two fields are mixed at a time. Once the optimal mixture for two fields has been found, they are combined to form the input to the next iteration of the algorithm. This process is repeated until a threshold in the objective function is met or insufficient changes are produced in successive iterations.