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Assessing the convergence of transdimensional inversion used for subsurface geometry reconstruction

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Classic inversion methods used in geoscience research adjust a predefined number of parameters to the observed data. There are several situations however, when it is advantageous to modify the number of parameters during the inversion process. Imaging methods can especially benefit from this methodology, as by keeping the number of inverse parameters flexible, variable model resolution could be achieved without involving additional prior information on the geometry. For models with discrete features such as discrete fracture network models, a flexible model parameterization could be essential as the number of discrete features are typically unknown. By using transdimensional inversion, discrete fracture network models could be well calibrated to tomographic data, without specifying the number of fractures in the model in advance.

The reversible-jump Markov Chain Monte Carlo (MCMC) method is the most commonly used transdimensional inversion algorithm today. By using the Metropolis-Hastings-Green acceptance criteria, this algorithm is capable of iteratively updating models and modifying their dimensionality on the fly. The model of each accepted iteration is stored in an ensemble, a set of model realizations which represent the posterior probability of the inverse problem. One of the greatest challenges when using any type of MCMC algorithm is to find the point in the sequence when the inversion can be stopped. By this point the inversion should have converged to the solution and the sampling of the posterior should be complete. In the case of transdimensional inversion it is not possible to follow the changes of individual parameters and to compute any parameter statistics through the Markov chain, as parameters could appear and disappear at any point in the sequence. This limits the applicability of classic convergence assessment methods that may be used for conventional MCMCs. To overcome this challenge, we convert all model realizations in the ensemble to a common dimensionality. A classical solution from statistics is to convert the models to a scalar indicator value. With geological imaging applications it is more convenient to project the multi-dimensional models into their realistic shapes, into 2-D or 3-D geological profiles. These representations are usually numerically easier to handle, and they can also be used for visualization purposes. We present some classical MCMC diagnostic tools applied to the common dimension representation of discrete fracture network models calibrated to tomographic hydraulic data to show how this approach could be feasible in practice.