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Assessing heat tracing experiment data sets for direct forecast of temperature evolution in subsurface models: an example of well and geophysical monitoring data

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Hydrogeological inverse modeling is used for integrating data and calibrating subsurface model parameters. On one hand, deterministic approaches are relatively fast but fail to catch the uncertainty related to the spatial distribution of model parameters. On the other hand, stochastic inverse modeling is time-consuming and sampling the full high-dimensional parameter space is generally impossible. Even then, the end result is not the inverted model itself, but the forecast built from such models.

In this study, we investigate a prediction-focused approach (PFA) in order to derive a direct statistical relationship between data and forecast without explicitly calibrating any models to the data. To derive this relationship, we first sample a limited number of models from the prior distribution using geostatistical methods. For each model, we then apply two forward simulations: the first corresponds to the forward model of the data (past), the second corresponds to the forward model of the forecast (future).

The relationship between observed data and forecast is generally highly non-linear, depending on the complexity of the prior distribution and the differences in the two forward operators. In order to derive a useful relationship, we first reduce the dimension of the data and the forecast through principal component analysis (PCA) related techniques in order to keep the most informative part of both sets. Then, we apply canonical correlation analysis (CCA) to establish a linear relationship between data and forecast in the reduced space components. If such a relationship exists, it is possible to directly sample the posterior distribution of the forecast with a multi-Gaussian framework.

In this study, we apply this methodology to forecast the evolution with time of the distribution of temperature in a control panel in an alluvial aquifer. We simulate a heat tracing experiment monitored with both well logging probes and electrical resistivity tomography. We show (1) that the proposed method can be used to quantify the uncertainty on the forecast both spatially and temporally and (2) that spatially-distributed data acquired through geophysical methods help to significantly reduce the uncertainty of the posterior.