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Data assimilation using Bayesian inference with efficient polynomial surrogates

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Bayesian inference provides a practical framework for data assimilation and uncertainty analysis. In this context, prior knowledge, nonlinearity of the system and measurement errors can be directly integrated into the posterior distribution of the parameters. The Markov Chain Monte Carlo Method (MCMC) is a powerful tool for generating samples from posterior distributions. However, MCMC usually requires a large amount of simulations, which is computationally demanding, especially when it comes to large-scale flow and transport models.

To solve this problem, we construct an alternative system for model output in the form of polynomials via stochastic collocation method. In addition, we use interpolation based on nested sparse grids and adaptively consider the different importance of parameters for high-dimensional problems. In case of strong non-linearity (such as discontinuous or non-linear relations) between the input parameters and the output response, we introduce additional transformation processes to improve the accuracy of the surrogate model. Once the surrogate system is built, we can evaluate the statistics with a very low calculation cost. The numerical results show that the method can efficiently estimate the posterior statistics of the input parameters and provide accurate results for the historical responses and prediction data.