Robust calibration of imperfect subsurface flow models using iterative ensemble smoothing

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Flow simulation in sub-surface reservoirs is a challenging task as the flow models are computationally expensive and contains a large number of unknown parameters. With the availability of cheap sensors, it now a common practice to calibrate the unknown model parameters using sparse and/or indirect measurements for example pressure response or saturation values at wells. Once the model is calibrated, it is then utilized for forecast, optimization and/or decision support. However, in many cases, the calibrated models fails to provide reliable predictions. One of the primary reasons for this lack of forecast skills – of the calibrate models – is attributed to neglecting the model inadequacy (aka. discrepancy) during the parameter estimation step. This is compounded by the large body of research in which different model calibration techniques are evaluated using test cases, with artificial calibration data that is generated using the same model used for the inversion (i.e. inverse crime).

In the current work, we formulate the parameter estimation problem as a joint estimation of the imperfect model parameter and a modeling errors component which is formulated as a random variable. The prior of the model error parameters is evaluated using an initial study, where the leading sources of the modeling error are investigated. We provide a disciplined approach on how to formulate these initial studies and provide two test cases where we study the errors originating from up-scaling and the errors due to the utilization of a simplified geological model parameterization.

Ensemble smoother with multiple data assimilation was utilized for Bayesian inversion and the results obtained, shows significant improvement in the quality of the estimated parameter when accounting for modeling errors. In terms of forecast skill, higher prediction accuracy/reliability is also observed. Moreover, the consistency between the different runs of the iterative ensemble smoother is improved when we included the modeling error component. We postulate that the true parameter posterior distribution is smooth, while the posterior distributing when neglecting the modeling error contains multiple peaks as the parameters are pushed to match the calibration data beyond the imperfect model capacity.