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Title Direct Selection of Stochastic Model Realizations Constrained to Historical Data
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Abstract

A new methodology for stochastic reservoir modelling constrained to well and historical data has been developed and successfully applied to synthetic case studies. Multiple well historical data and prior geostatistical information can be integrated using a Bayesian inversion technique and an efficient optimization algorithm based on the gradient method. This inversion procedure allows direct selection of particular constrained model realizations within a confidence domain of the parameter space.

The gradient method, implemented in an industrial numerical reservoir simulator within the fully implicit scheme, provides the sensitivities of production results with respect to the model parameters. These parameters can be, for example, the petrophysical properties over given reservoir zones or the well productivity indexes. Recently, a user-defined parameterization technique of a heterogeneous permeability distribution was introduced in order to locally modify the mean value of an initial stochastic distribution.

An efficient quadratically convergent optimization algorithm is combined with the Bayesian formalism to directly obtain a constrained model from an initial realization. Greater efficiency of this procedure is reached by using the gradient results. A priori information on the parameters is introduced through Gaussian or lognormal probability density functions. A maximum likelihood model is obtained after history matching, as well as a posteriori information on the parameters with reduced uncertainties.

After history matching, new model realizations can be selected, inside a confidence domain defined by an iso-probability criterion, in order to quantify production forecast uncertainties. An optimization procedure is used to obtain particular model realizations, which correspond to extreme values of a given production forecasting criterion.

A successful application on a synthetic case study is described at the end of this paper. The petrophysical properties and the activity coefficient of an analytical aquifer are simultaneously constrained to match the historical data recorded for 7 wells. A parameterization technique is used in order to constrain the mean of a stochastic distribution of petrophysical properties.

Introduction

Our aim is to constrain geostatistical models to both well data and historical data. The proposed method is based on the Bayesian inversion technique, whose formalism is well-suited for integrating prior knowledge on the geological model and the dynamic data. Moreover, this formalism positions the inverse problem in a stochastic context, allowing uncertainty quantification on production forecasts.

The main difficulty encountered in constraining geostatistical models is the cost in terms of CPU time spent to obtain a constrained realization and the amount of realizations needed to quantify uncertainties on production forecasts. The dimension of the inverse problem corresponds, theoretically, to the number of grid blocks multiplied by the number of petrophysical properties to be identified. A reduction of the dimension of the inverse problem is therefore necessary to preserve the feasibility of such methods. A parameterization of the distribution of the petrophysical properties can be used in order to reach this goal. The principle of the proposed method is to define the distribution of petrophysical properties as a function of parameters in a reduced space and to constrain these parameters to the production data. This paper proposes a parameterization technique, called pilot point method, which consists in constraining the initial model to several master points, located on a coarse grid. Each master point locally constrains the mean of an initial model realization.

The gradient method can be used to improve the efficiency of the inversion procedure. The sensitivities of the simulations results with respect to the master point values can be used by an optimization algorithm.