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An overview of parameterization techniques for history-matching

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Production forecasting is part of the existence of the oil and gas industry: it contributes to generate improvements in operations.

A key tool to tackle this problem is the building of reservoir models that describe the properties of the underground hydrocarbon reservoirs. Clearly, the value of such models strongly depends on their abilities to accurately predict the displacements of fluids within reservoirs. This is the reason why it is essential that reservoir models reproduce at least the data already collected. Data-consistent models are more reliable.

The data considered are split into two groups: static and dynamic data. Static data do not vary with time. They include for instance measurements on core samples extracted from wells or logs used to describe electrofacies and petrophysical variations along wells. However, such direct measurements of geological and petrophysical properties are very sparse and sample only a small reservoir volume. They have to be supplemented by indirect measurements, mainly 3-D seismic. The second group of data includes dynamic data, i.e., data which vary with time because they depend on fluid flows. They mainly comprise production data, i.e., data measured at wells such as bottom hole pressures, oil production rates, gas-oil ratios, tracer concentrations, etc. Anyway, we end up with only little information about the spatial distributions of facies, porosity or permeability within the targeted hydrocarbon reservoirs. These facies/petrophysical properties can be considered as realizations of random functions. They are very specific because of two essential features: they include a huge number of unknown values and they have a spatial structure.

The purpose of reservoir modeling is to identify facies and petrophysical realizations that make it possible to numerically reproduce the dynamic data while still respecting the static ones. Different approaches can be envisioned.

A first possibility consists in randomly generating realizations, then in simulating fluid flow for each of them to see whether they reproduce or not the required data. The process is repeated until identifying a suitable set of facies/petrophysical realizations. The second approach is pretty close. The idea behind is still to screen the realization space, but without performing any fluid flow simulation to check the suitability of the realizations. This strongly depends on the definition of a meaningful criterion to characterize the dynamic behavior of the considered set of realizations without running flow simulations. We may also randomly generate a starting set of facies/petrophysical realizations and run an optimization process aiming to minimize an objective function by adjusting the realizations. A key issue is then how to simultaneously adjust so many parameters while preserving the consistency with respect to the static data. This motivated many research works over the last 20 years, resulting in the development of several parameterization techniques. One of the very first was the pilot point method introduced by de Marsily (1984). Since, variants and other parameterization techniques have been proposed. We aim to review some of them and focus on how useful they are depending on the problem to be faced.