Uncertainty Quantification for Stratigraphic Modeling

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ABSTRACT

Numerical stratigraphic forward models can help to estimate sediment distribution and characteristics at regional to basin scales. However, the available data - usually regional seismic and scarce well data- may not be sufficient to accurately constrain all the processes and parameters. The resulting uncertainty impacts the confidence in the simulation results of the stratigraphic modeling, and therefore in its capacity to assess exploration risks.

To properly take this uncertainty into account, basin-scale sediment distribution needs to be simulated for a wide range of possible values for the uncertain parameters. However, this requires a large number of simulations and remains hardly feasible in practice due to the required computation time. Another important issue with uncertainty quantification is the processing of the results and the information that can be retained with respect to the problem at hand. Existing studies usually consider scalar outputs only, such as the total volume of reservoir. However, from an exploration perspective, much more interesting information can be obtained from space dependent properties, such as the distribution in the basin of the sediment thickness, facies proportion or environment of deposition.

In this study, we propose to perform sensitivity analysis and uncertainty quantification on the spatial outputs of a stratigraphic forward model. To that purpose, we introduce analytical functions that approximate the simulator output properties, called proxy models (or response surfaces). If these models provide accurate estimations for the outputs, they can be used instead of the simulator for uncertainty quantification. In this case, only the simulations needed to build the proxy models are required. Then, different applications can be envisioned without any additional simulations, what can lead to faster risk assessment. The classical proxy model approach provides estimations for scalar outputs. Here, we rather apply an extension of this approach to space dependent outputs, that was successfully used for other applications such as reservoir engineering. The objective of this work is then to investigate the potential of such proxy models in the context of stratigraphic modeling, in terms of computation time and inferred information.

To that purpose, a synthetic case representative of a passive margin is considered, with uncertain continuous parameters related to the three main processes involved in a sedimentary basin formation: accommodation, sediment supply and sediment transport. First, a sample of the parameters is generated according to their uncertainty range. The corresponding simulations are then used to estimate the spatial distribution of the sediment thickness and facies proportions, providing satisfactory predictions on the whole. The proxy models are then used for various studies. First, a quantitative sensitivity analysis is performed, that provides an estimation of the parameter influence on the outputs. More specifically, this influence is quantified in each grid block, so that the most influential parameters can be highlighted in each part of the basin. This could help to discard the less influential parameters in a future calibration process. Risk analysis is also considered. The sample resulting from a Monte-Carlo simulation can be processed in different ways depending on the problem at hand.

The methodology applied to stratigraphic forward modeling appears as a promising trade-off between simulation time and inferred information. It provides very interesting results such as estimated maps of reservoir presence probabilities.