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Probabilistic inversion of AVO seismic data for reservoir properties and related uncertainty estimation

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Sought-after reservoir properties of interest are linked only indirectly to the observable geophysical data which are recorded at the earth's surface. In this framework, seismic data represent one of the most reliable tool to study the structure and properties of the subsurface for natural resources. Nonetheless, seismic analysis is not an end in itself, as physical properties such as porosity are often of more interest for reservoir characterization. As such, inference of those properties implies taking into account also rock physics models linking porosity and other physical properties to elastic parameters. In the framework of seismic reflection data, we address this challenge for a reservoir target zone employing a probabilistic method characterized by a multi-step complex nonlinear forward modeling that combines: 1) a rock physics model with 2) the solution of full Zoeppritz equations and 3) a convolutional seismic forward modeling.

The target property of this work is porosity, which is inferred using a Monte Carlo approach where porosity models, i.e. solutions to the inverse problem, are directly sampled from the posterior distribution. From a theoretical point of view, the Monte Carlo strategy can be particularly useful in the presence of nonlinear forward models, which is often the case when employing sophisticated rock physics models and full Zoeppritz equations and to estimate related uncertainty. However, the resulting computational challenge is huge. We propose to alleviate this computational burden by assuming some smoothness of the subsurface parameters and consequently parameterizing the model in terms of spline bases. This allows us a certain flexibility in that the number of spline bases and hence the resolution in each spatial direction can be controlled. The method is tested on a 3-D synthetic case and on a 2-D real data set.