Probabilistic modeling of caprock leakage from seismic reflection data CO2-EOR

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We illustrate a methodology which helps to perform a leakage risk analysis for a CO2 reservoir based on a consistent, probabilistic approach to geophysical and geostatistical inversion. Generally, risk assessments of storage complexes are based on geological models and simulations of CO2 movement within the storage complexes. The geological models are built on top of geophysical data such as seismic surveys, geological information and well logs from the reservoir or nearby regions. The risk assessment of CO2 storage requires a careful analysis which accounts for all sources of uncertainty. However, at present, no well-defined and consistent method for mapping the true uncertainty related to the geophysical data and how that uncertainty affects the overall risk assessment for the potential storage site is available.

To properly quantify the uncertainties and to avoid unrealistic simplifications, we propose a consistent combined seismic and petrophysical modeling in a probabilistic framework. We model the reservoir as a simplified synthetic 2-D pixel-based model, parametrized through rock type, seismic P-wave velocity, density and porosity at each point of a regular grid. Uncertainties are then modeled at each step of data collection, data processing, data interpretation, geostatistical inversion and petrophysics by means of probability density functions. Moreover, fault zones are not represented as zero thickness planes in a structural modeling fashion but as possible extended zones characterized by no continuous reflectors in the seismic data and anomalous physical properties. In addition to leaky faults, since we model also porosity, our model can contain areas in the caprock where high porosity may result in high permeability, giving rise to possible leaks. Thus the reservoir is a realization of a geostatistical model generated with the help of geological expert knowledge and available prototype models. Employing a Markov chain Monte Carlo method, we generate many realizations of the geostatistical model consistent with our a priori knowledge (in the form of prototype images, well logs data, etc.) and test them to find out which models satisfy the observed seismic data. Our algorithm samples the probability distributions of reservoir parameters, including the distribution of a rough measure of the overall transmissivity of the caprock, so that finally a set of solutions containing all needed information for subsequent risk analysis is found.