Quantifying the efficiency of surveillance strategies for subsurface CO$_2$ storage applications

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Abstract

One of the main challenges in subsurface CO$_2$ storage applications concerns the mitigation of technical risks. In particular the uncertainty regarding the storage capacity and conformance of subsurface storage sites to the injection plan can be a serious threat to the success of CO$_2$ storage projects. Economic aspects are also paramount to the success of these projects; reducing the costs and risk in storage operations is one of the keys to the deployment of large-scale carbon capture and storage.

The design of cost-efficient monitoring systems plays an important role in this context, as a means of producing, with minimal costs, sufficient evidence of the behavior of the storage sites. Due to the large variety of sensing technologies available, it can be a challenge for operators to choose which measurements to gather. In this work we present a practical workflow to assist operators (and regulators) in quantifying the efficiency of potential surveillance strategies as a first step to optimize the design of monitoring systems. The workflow uses uncertainty quantification, data assimilation and different metrics to derive a measure of the efficiency of a surveillance strategy and the expected contribution of the future measurements.

As the basis for our workflow we use an ensemble of models that is generated in accordance with presumed uncertainties in the properties of the storage site, including the storage reservoir, the overburden and the wells. This ensemble can be updated whenever measurements are obtained that provide information about these uncertainties. They can also be simulated forward in time to provide a baseline for conformance determinations. Any statement on conformance will have to account for the uncertainty in data as well as in the models. We therefore first discuss the need for use of statistical tests to be able to make statements about conformance and distinguish between tests based only on data and test based on both data and models.

We apply the proposed workflow to a hypothetical CO$_2$ storage site model containing a leak in the overburden. The leak has uncertain properties (i.e., flow conductivity, location). We consider a simple yet realistic case study to illustrate the procedure. We compare different metrics to define the efficiency of the surveillance strategy, which depends on the objective of the operator with the monitoring activities. Thereafter, we study the sensitivities of these metrics to different surveillance strategies, varying measurement noise levels, varying spatial and temporal measurement frequencies and other parameters. This is done in order to set up the basis for optimizing monitoring configurations. We conclude with an analysis of the results and a discussion on the next steps for future research.
Due to its modular nature, the proposed workflow is readily expandable to all measurement types. The methodology is relevant for the problem of designing monitoring systems to verify conformance of CO₂ storage sites and is practical in terms of computational costs required. The proposed workflow provides practitioners with a framework to quantify the expected contribution of a surveillance strategy to the assessment of storage complex performance, something which is currently not possible.

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