Description of doctoral project and research results achieved to date

This work addresses challenges related to mathematical and numerical modeling of flow in porous media. To address these challenges, two applications are considered: firstly, counter-current two-phase flow in a heterogeneous porous media and secondly, polymer flooding in the context of enhanced oil recovery. Furthermore, an upscaled model for CO₂ migration is used to estimate effective rates of convective mixing from commercial-scale injection.

Numerically, the upstream mobility scheme is widely used to solve hyperbolic conservation laws. For flow in heterogeneous porous media there exists no convergence analysis for this scheme. Studies of the convergence performance of this scheme are important due to the extensive use of the upstream mobility scheme in the reservoir simulation community. We show that the upstream mobility scheme may exhibit large errors compared to the physically relevant solution when applied to a counter-current flow in a reservoir where discontinuities in the flux function are introduced through the permeability. A small perturbation of the relative permeability values can lead to a large difference in the solution produced by the upstream mobility scheme. Not only does the scheme encounter large errors compared to what is considered to be the physically relevant solution, but the solution also lacks entropy consistency.

High-resolution schemes are often used for model problems where high accuracy is required in the presence of shocks or discontinuities. Polymer flooding represents such a system and is a difficult process to model, especially since the dynamics of the flow lead to concentration fronts that are not self-sharpening. The application of modern high-resolution schemes to a system that models polymer flooding is considered and different first- and higher-order schemes are compared in terms of how the discontinuities are treated. Through numerous numerical experiments some special numerical artifacts of the polymer system are uncovered. The need of high-resolution schemes and the importance of their applicability for the polymer problem is addressed.

The process of CO₂ migration ranges over multiple scales and results in challenges when it comes to modeling and simulation of this system. This expresses the need for a upscaled model and upscaled parameters that can capture both large and small-scale spatial and temporal effects. The ongoing CO₂-injection at the Utsira formation is considered as a field-scale study for CO₂ storage. Through an upscaled model for CO₂ migration we get the first field-scale estimates of the effective upscaled convective mixing rates in this context. The findings are comparable but somewhat higher than reported in the existing literature based on fine-scale numerical simulations. Our work validates the use of numerical simulations to obtain upscaled convective mixing rates, while at the same time validating that convective mixing is an important quantifiable storage mechanism at the Utsira formation. To account for uncertainties in the description of the storage formation, sensitivity studies are conducted relative to some of the most uncertain parameters.