successful news
SUbsurface CO2 storage- Critical Elements and Superior Strategy
Newsletter from the SUCCESS centre – March 2015 – no. 17

CO_2 and oil in geological formations

December 19th last year Trine Solberg Mykkeltvedt became the first of the PhD candidates directly funded by FME SUCCESS to get her degree. Her thesis was on "Numerical solutions of two-phase flow with applications to CO_2 sequestration and polymer flooding".

The thesis addresses challenges related to mathematical and numerical modeling of flow in porous media. Two applications are considered:

- counter-current two-phase flow in a heterogeneous porous media:
- polymer flooding in the context of enhanced oil recovery (EOR).

Furthermore, an upscaled model for CO_2 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.

Trine shows 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 CO_2 migration ranges over multiple scales and results in challenges when it comes to modeling and simulation of this system. This expresses the need for an upscaled model and upscaled parameters that can capture both large- and small-scale spatial and temporal effects. The

Foto: Erik A. Hanson

ongoing CO_2 -injection at the Utsira formation is considered as a field-scale study for CO_2 storage.

Through an upscaled model for CO_2 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 finescale numerical simulations. The thesis 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.

The thesis is available at *https://bora.uib.no/handle/1956/9666.*

Reducing the model uncertainties

February 13th Kristian Fossum defended his PhD thesis on "Assessment of Sequential and Simultaneous Ensemble-based History Matching Methods for Weakly Non-linear Problems".

The ensemble Kalman filter (EnKF) has, since its introduction in 1994, gained much attention as a tool for sequential data assimilation in many scientific areas. In recent years, the EnKF has been utilized for estimating the poorly known petrophysical parameters in petroleum reservoir models. The ensemble based methodology has inspired several related methods, utilized both in data assimilation and for parameter estimation. All these methods, including the EnKF, can be shown to converge to the correct solution in the case of a Gaussian prior model, Gaussian data error, and linear model dynamics. However, for many problems, where the methods are applied, this is not satisfied. Moreover, several numerical studies have shown that, for such cases, the different methods have different approximation error.

Considering parameter estimation for problems where the model depends on the parameters in a non-linear fashion, this thesis explore the similarities and differences between the EnKF and the alternative methods. Several characteristics are established, and it is shown that each method represents a specific combination of these characteristics. By numerical comparison, it is further shown that a variation of the characteristics produce a variation of the approximation error.

A special emphasis is put on the effect of one characteristic, whether data are assimilated sequentially or simultaneously. Typically, several data types are utilized in the parameter estimation problem. In this thesis, it is assumed that each data depends on the parameters in a specific non-linear fashion. Considering the assimilation of two weakly non-linear data with different degree of non-linearity, it is shown, through analytical studies, that the difference between sequential and simultaneous assimilation depends on the combination of data.

Via numerical modelling, Kristian investigates the difference between sequential and simultaneous assimilation on toy models and simplified reservoir problems. Utilizing realistic reservoir data, he shows that the assumption of difference in non-linearity for different data holds. Moreover, he demonstrates that, for favourable degree of nonlinearity, it is beneficial to assimilate the data ordered after ascending degree of nonlinearity.

The thesis is available at *https://bora.uib.no/handle/1956/9398*.

Foto: UiB

CLIMIT Summit 2015:

Broad SUCCESS presence

The CLIMIT SUMMIT has become an established meeting place for the CCS community. In 2015, this event was held 24-25 February at the Soria Moria Hotel and Conference Centre in Oslo.

The conference attracted 230 participants, 30 presentations and 80 posters. The SUCCESS Centre was well represented at the meeting with Centre Manager, Scientific leaders, Work Package leaders and leading scientist.

There were four presentations held by SUCCESS/INJECT:

- Magnus Wangen: Injection well management
- Guttorm Alendal: The footprint of CO_2 leak to marine water
- Ivar Aavatsmark: New models for CO_2 capacity of North Sea aquifers
- Arvid Nøttvedt: Large-scale storage project

Furthermore, we had three posters, one for each of our work packages: Reservoir, Containment and Monitoring. Our collaborative projects LCSANS, PROTECT, CONQUER, COPASS and LYB CO2 lab also were presented.

LYBCO2 Phase 2 project finalized

Apart from Plug and Abandonment (P&A) of two wells the Longyearbyen CO2 Phase 2 project is finished, and currently write up the final report. This has been a project that FME SUCCESS is grateful to have been a part of. Large datasets have been compiled and important scientific results have been achieved.

Some of the results is recently published and the papers are available on the open access by the *Norwegian Journal of Geology* 2014 vol. 94 nos. 2 and 3.

Working to become next generation FME centers

FME SUCCESS and most other Centers for environment friendly energy will finish their work in 2017 or early 2018.

The Research Council has now started the process of establishing a new group of centers that might start as early as 2016. Applicants are these days finalizing their first step proposal sketch, which has a deadline April 1st. Sketches that are approved can be extended to a full proposal to be delivered by late November.

Several SUCCESS partners are known to be working on sketches, and the center management has also been active in trying to extend the fruitful companionship we have in our center.

New article on tracing subsea CO_2 leakage

The article describes a technique that can to be used monitor subsea CO_2 sequestration projects. The study describing this has been done as part FME SUCCESS, the work led by PhD student Helle Botnen.

Botnen, Omar, Thorseth, Johannessen and Alendal (2015): "The effect of submarine CO_2 vents on seawater: Implications for detection of subsea carbon sequestration leakage". *Limnology and Oceanography*, 60: 402–410.

Read more at the UNI website (*http://uni.no/en/news/2015/03/24/tracing-subsea-co2-leakage/0*) or follow this *doi:10.1002/lno.10037*.

SUCCESS (Subsurface CO_2 Storage – Critical Elements and Superior Strategy) is one of several Norwegian centres for environment-friendly energy research, funded by the Norwegian Research Council and industry partners. For more info and contact address: *www.fme-success.no*.

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