successful news
SUbsurface CO2 storage- Critical Elements and Superior Strategy
Newsletter from the SUCCESS centre – May 2017 – no. 24

First generation FMEs are finishing

Eight successful years

The eight first Centres for Environment-friendly Energy Research have now mostly finished their work. May 22nd the Research Council rounded up the activities with a conference where the centres Solar United, NORCOWE, CenBio, CEDREN, NOWITECH, BIGCCS, ZEB and our own SUCCESS presented results. It was quite obvious that this scheme has given loads of first class research. Still there is a way to go before we see much of the "new" technology in large-scale use.

At the conference scientific leader Per Aagaard presented results from SUCCESS, noting especially that the centre has had more than 500 articles, papers and presentations. The latter years we have had more than thirty level-2 scholarly articles published every year. Cue words among scientific results were mapping of storage sites, new equations-of-state, injectivity issues, fluid dynamics, multiphase simulations (vertical equilibrium), sensitivity studies, long-term trapping of CO_2, geomechanical integrity, geophysical and marine monitoring and more – and altogether the last years integration of all these findings.

Most of the eight centres have had their own summing-up conferences, but as the youngest of the siblings, SUCCESS is still running till the end of 2017. The centre plans to stage a national conference early spring of 2018 entitled **Future Perspectives on Carbon Capture and Storage**. This conference aims at looking beyond the current status of CCS and bring to table a wider view on relevant and critical issues that are important to successful deployment and acceleration of CCS.

Happy representatives from the centres; our Per second right. Photo: RCN

Doctor on simplified models

Odd Asbjørn Andersen received his PhD degree at the University of Bergen in February. His thesis is titled "Simplified models for numerical simulation of geological CO_2 storage".

Numerical simulations will play an important role in order to estimate what quantities as practical can be stored and how confident we can be that the gas stays where it should for thousands of years.

Current simulation technology has been developed to study the production of oil and gas and is less well suited to study large storage problems. Andersens's thesis presents an alternative approach, where simple calculation models are used in a flexible framework. The work contributes to the field of mathematical modeling of CO_2 storage with several new developments.

In the spirit of promoting reproducible computational research, most of the computer code underlying his results has been made freely available as open software in the form of a separate module, MRST-co2lab, to the MATLAB Reservoir Simulation Toolbox (MRST), developed, maintained and published by the Computational Geosciences group of SINTEF ICT, Department of Applied Mathematics. The exception is the work on geomechanics, which has not yet been made part of the public code, but is in the pipeline for a future release.

Odd Andersen has been a part of FME SUCCESS through our collaborative project MatMoRA II, hosted by University of Bergen, and he also kept his employment at SINTEF ICT.

Link in Bora:
http://bora.uib.no/handle/1956/15477
Articles:
http://bora.uib.no/browse?value=Andersen%2C+Odd&type=author

Coming up

SUCCESS manager Arvid Nøttvedt will give one of the keynote talks at the 9th Trondheim Conference on CO_2 Capture, Transport and Storage which takes place June 12–14.

https://www.sintef.no/projectweb/tccs-9/

Upslopes and isotopes

SUCCESS postdoc Anja Sundal at UiO has recently started up two new CLIMIT projects that each in its own way may contribute to safe CO_2 storage.

The first project was initialized when Anja last year received a UiO Energy grant to visit Eawag/ETH in Zürich to follow up earlier work on isotope-geochemistry in groundwater, an underexplored topic in Nordic countries and potentially very useful in CO2 storage and monitoring schemes.

It turned out that Eawag has developed a mobile mass-spectrometer that measures noble gases and CO_2, and the question that arised was if this instrument is suitable for geochemical and quantitative monitoring of subsurface CO_2 storage.

An application to Gassnova (CLIMIT demo) resulted in a small grant to do a feasibility study, «Monitoring isotope distribution in gas and water for safe storage of CO2 on the Norwegian shelf (ICO2P)». This project is also supported by Statoil.

Anja also has obtained a two year researcher project from the Research Council side of CLIMIT: «Optimized CO_2 storage in sloping aquifers (CO_2 Upslope)». This project will challenge some common concepts in reservoir characterization for CO_2 storage by re-evaluating proper methods for estimating storage volumes, including enhanced trapping efficiency during migration in sloping aquifers. Collaborating partners are Sintef Digital and GEUS (Denmark). Rohaldin Miri, who obtained his PhD through SUCCESS (Inject project) in 2015, will be affiliated part-time to the project. Miri now is employed at Petroleum University of Teheran.

The portable mass spectrometer on Soppensee (Switzerland). Photo: EAWAG – Swiss Federal Institute of Aquatic Science and Technology

The lady is back

SUCCESS head of all kinds of stuff Charlotte Krafft is back from maternity leave and will guide the centre through its last year. We thank her stand-in **Tor Langeland** for excellent work in her absence.

SUCCESS wishes you all a summer filled with sandy beaches and stones!

CONQUERing the uncertainties

SUCCESS collaborating project CONQUER is a research project funded by the Norwegian Research Council. It started in 2015 and involves staff from Uni Research and University of Bergen.

In addition, the project collaborates with external partners and co-authors from University of Colorado Boulder, Stanford University, ETH Zurich, Royal Institute of Technology and Linköping University. The international collaboration will be further strengthened through a scholarship for Daniel Olderkjær to visit the Uncertainty Quantification Group at University of Colorado during September to December 2017.

The goal of CONQUER is to develop numerical methods for simulation of CO_2 storage including uncertainty quantification (UQ). Most existing UQ techniques are tailored to smooth problems with smooth parameter dependence. In heterogeneous storage formations for CO_2, this is typically not the case. The input problem (heterogeneous reservoirs with highly varying properties) as well as the output problem (e.g. capture the saturation profiles in the same reservoirs) are addressed in CONQUER. A detailed geological description is of little use if it is prone to significant uncertainty.

Since uncertainty is the main focus of this project, some of the less important physical features are sacrified to provide the simulations with uncertainty estimates, e.g., confidence intervals. This is done through the development of numerical methods for vertical-equilibrium models where stochastic variables are incorporated directly into the solvers for flow, transport and geomechanics. The research activities are organized in four work packages:

- WP1: Efficient pressure solvers for stochastic heterogeneous inputs: techniques from machine learning (large data sets) and compressive sensing.
- WP2: Reduced-physics solvers for the transport of CO_2 in aquifers: stochastic solvers that can handle sharp features.
- WP3: Stochastic geomechanics models: new solver features to UiBs geomechanics software.
- WP4: Framework for error and uncertainty analysis: coupling and balancing of errors.

Expected Outcomes

- Computational framework for balancing uncertainties and numerical errors.
- Robust methods tailored to the subproblems (pressure, geomechanics, transport).
- Best-practice guide for mathematical representation of uncertainty in CO_2 storage.
- Open source software for uncertainty quantification.

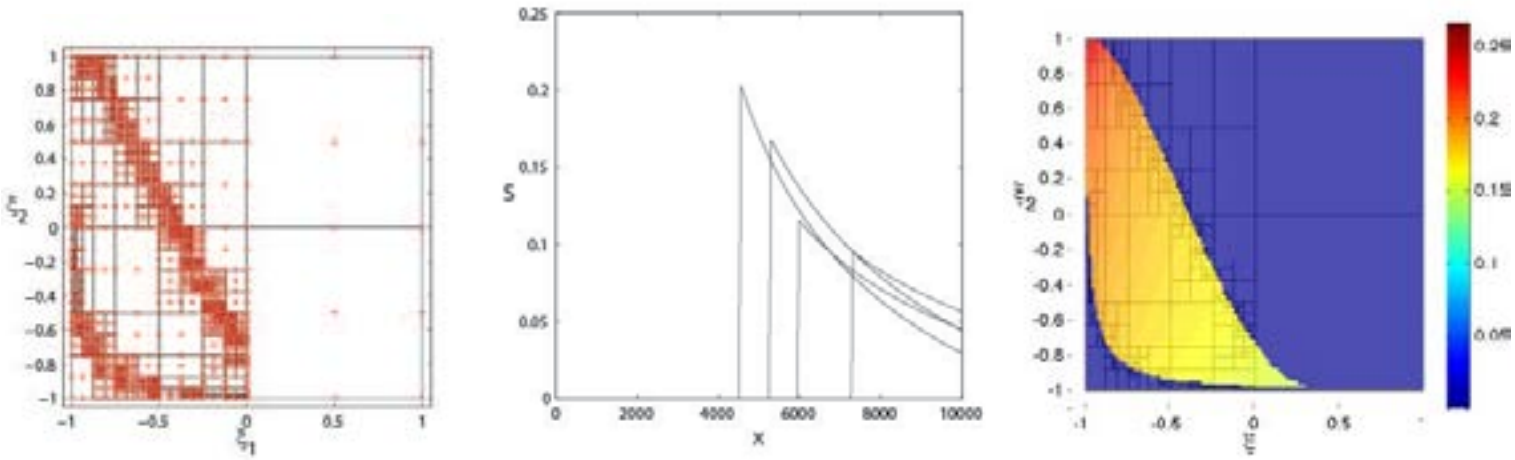
Per Pettersson (Uni Research), project manager CONQUER (Photo: Marit Hommedal)

CONQUER research activities – an example

Consider a simplified radial model for the subsurface transport of CO_2 under uncertain mobility ratio and permeability. Small variations in these parameters may have significant impact on the output saturation profiles (figure 1(a)). Reliable UQ requires knowledge of when a small change in the parameters has a large effect on the saturation.

Figure 1(b) demonstrates an adaptive method to search for the output effect in the input space (permeability and mobility ratio). Red dots denote transport simulations evaluated at different coordinates in input space. The method adds more resolution in parameter regions of large variation, as confirmed by figure 1(c) that depicts the exact saturation for this problem as a function of the input parametric variables. If one was to search the entire domain to obtain similar resolution it would take 170 times as many transport simulations.

With more uncertain parameters, the effect would be even more pronounced. On the negative side, the method misses the right bottom tail of the plume in parameter space. The project partners aim to develop more effective level set methods that solve the problem at lower numerical cost.



- (a) Saturation profiles for different permeability and mobility ratio 400 years after injection at x = 2500 stops.
- (b) Critical regions are identified adaptively in stochastic space (ξ1–ξ2), here depicted at the location x = 5000 m.
- (c) In this case the method can be validated against an exact solution. Computations are concentrated to regions of large variance.

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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