Carbon capture and storage: towards predictive modelling of reservoirs and solutal convective turbulence in porous media

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External stakeholder(s): Schlumberger-Doll Research Centre, Boston MA, USA

Scientific background

Carbon Capture and Storage is considered to be one of the most viable near-term implementable approaches for reducing anthropogenic carbon dioxide emissions to the atmosphere. The idea is to capture carbon dioxide from so-called point sources such as power stations, purify and compress the gas, and store it in porous formations underground. Australia is presently at the forefront of international research efforts. A poorly understood aspect is the rate at which carbon dioxide mixes and dissolves into host fluid (usually a brine). This process has both academic and industrial interest. Academically, dissolution is thought to occur partly by convection and there is significant room for fundamental fluid dynamics contributions [1]. Industrially, up-scaled models are of interest to the Schlumberger-Doll Research Centre for incorporation into reservoir simulators. Dr. Slim has researched this problem as a scientist at Schlumberger. Her work is nearing a predictive up-scaled model.

Research challenge

The mathematical model governing the dynamics of a CO2 plume in a reservoir is a variant of a nonlinear diffusion equation known as the Porous Medium Equation [2]. An outstanding problem is that numerical simulations of this equation cannot resolve all the scales of motion present in a real CO2 plume. They have a minimum scale of resolution set by the numerical grid. Most of the mixing of CO2 happens on scales smaller than the grid. It is therefore necessary to parametrise the sub-grid dynamics. The challenge of this project is to develop a stochastic model which mimics the sub-grid dynamics sufficiently accurately to allow the total rate of dissolution of CO2 to be predicted. A similar problem exists in dealing with turbulent sub-grid motion in atmospheric dynamics. A class of statistical models known as 'moment-closure models' exist in the literature. In this project, you will adapt and validate such models to the case of the Porous Medium Equation. In a sense, you will develop a statistical theory of 'turbulence' for a nonlinear PDE which is not the Navier-Stokes equation.

Pre-requisites

- You should have a strong background in mathematical modelling of complex systems and a scientific interest in stochastic models, nonlinear partial differential equations and numerical methods.
- You should care about the research themes falling under the umbrella of Warwick's Energy GRP (http://www2.warwick.ac.uk/research/priorities/energy/) since this is the research area you will be best qualified to work in after you graduate.
- You should be willing and able to make a couple of research trips of several weeks each to Melbourne during your studies.

Additional considerations

This project is offered as a MathSys MSc project only and may offer the possibility of a follow-on PhD project. The project is supported by the Monash-Warwick Alliance as part of a collaboration between the Warwick Centre for Complexity Science and the Monash Academy for Cross and Interdisciplinary Mathematical Analysis (MAXIMA). Additional travel funds are available to allow the student to make several trips to Melbourne to work with Dr. Slim.

References

[1] Anja C Slim, MM Bandi, Joel C Miller, and Lakshminarayanan Mahadevan. Dissolution-driven convection in a hele–shaw cell. *Physics of Fluids (1994-present)*, 25(2):024101, 2013.

[2] Anja C Slim. Solutal-convection regimes in a two-dimensional porous medium. *Journal of Fluid Mechanics*, 741:461–491, 2014.