The H-Cube Project: Hydrodynamics, Heterogeneity and Homogenization in CO2 storage modeling

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Key words: multiphase flow, up-scaling, ranking, multi-mesh methods

Introduction

The main goal of the project H-CUBE is to provide appropriate theoretical and numerical models for accurate evaluation of the hydrodynamic behavior of a CO2 storage complex and surrounding area. Particular emphasis will be placed on the determination of the CO2- brine flow with buoyancy forces and dissolution effect in saline aquifers with a methodology for assessing heterogeneity of the geological formations at several scales. This will consist in performing deeper studies on the impact of heterogeneities onto CO2 flow behaviors from near well injection zone (meter scale) to basin scale (~100km), in developing new techniques for optimizing the flow behavior simulation (up-scaling and homogenization techniques) and characterization (proposal of appropriate reservoir descriptors), and in proposing suitable modeling and statistical workflows for assessing uncertainty analysis in function of the envisaged geological contexts. The project is decomposed in four main work packages.

Up-scaling processes

We propose to assess the buoyant forces on the CO2 and brine vertical migration into a heterogeneous system. The approach is proposed in a two folds fashion by using both analytical and numerical up-scaling methods. Analytical up-scaling techniques are attractive options because they are computationally efficient and convenient to implement in coarse grid models [1]. We propose to derive an analytical expression for effective multiphase flow properties in a laminar heterogeneous porous media generated with three level of complexity.

Heterogeneity and model ranking

When dealing with multiple realization of heterogeneity field distribution on the same 3D static earth model appropriate ranking measures of the static realizations should be defined to select the limited number of geological realizations that will serve as inputs for flow simulations. We propose to define different geometrical and topological descriptors of the porous rock network to characterize a priori reservoir dynamic behavior [2].

Dual Mesh method

Detailed geological models typically contain many more cells than can be accommodated by reservoir simulation due to computer time and memory constraints. However, predictions performed on a coarser up-scaled mesh are inevitably less accurate than those performed on the initial fine mesh. An alternative approach is to retain fine scale information while avoiding the most time consuming feature of the simulations, solving for the flow field on this fine grid. This can be achieved through solving the pressure equation at the coarse scale using appropriately up-scaled properties. Heterogeneity at the fine scale can be introduced during the saturation update by using either a pressure or a flux refinement. In this case, the precision in fluid recovery is considerably improved and the CPU time and memory are much lower than for a full fine scale simulation [3].

Application to case studies

In order to validate the methods previously described, a number of real case studies are envisaged for a direct application of the different methods developed above, and of the integration of the simulation results to a comprehensive analysis. The objective is (i) to manage six case studies of static earth reservoir models with different geological contexts [4].

References

[1] Mouche E., Hayek M., Mügler C., 2010, Upscaling of CO2 vertical migration through periodic layered porous medium: the capillary-free and capillary dominant cases, Adv. in Wat. Res., 33, pp 1164-1178.

[2] Viseur, S., 2010, Automated methods for fully exploring and interpreting LIDAR data points. 72nd EAGE Conference & Exhibition incorporating SPE EUROPEC 2010, Barcelona, Spain.

[3] Guérillot D.R., Verdière S. Different pressure grids for reservoir simulation in heterogeneous reservoirs, SPE29148, 1995.

[4] Issautier, B., Viseur, S., Audigane, P., Le-Nindre Y-M., 2014, Impacts of fluvial reservoir heterogeneity on connectivity: implications in estimating geological storage capacity for CO2, Int. J. of Greenhouse Gas Control, In Press.