Comparison of numerical simulators for underground non-isothermal CO_2 injection in deformable saline aquifers

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We summarize the results obtained from a code-inter-comparison study initiated within the TRUST project financed by the European Community's 7th Framework Programme, addressing the injection of carbon dioxide (CO_2) in saline geological formations. Four numerical simulators are used to model multi-phase flow in porous media, and the effects of interests arising during CO_2 injection (e.g., CO_2 plume shape, fluid pressure and temperature evolution, deformation, etc.) are compared. Code-inter-comparison/benchmarking, represents a methodology for verifying, testing and comparing the available modelling tools. Such benchmarking studies have increased in popularity during the last decades (e.g., Class et al. 2009; Nordbotten et al. 2012; Flemisch et al. 2017).

Three benchmark test examples are defined with gradual increase in their physical complexity, starting with a two-phase two-component isothermal problem, then including non-isothermal effects, and finally, geomechanics. The reservoir properties are defined from mean calculated parameters from a database of approximately 2500 reservoirs.

The first benchmark example proposes CO_2 injection through a vertical well in a homogeneous, isotropic, horizontal deep saline aquifer without considering mechanical, chemical and thermal effects. An industrial scale injection rate of 30 kg/s, which corresponds to approximately 1 Mt/year, is simulated. Due to the symmetry of the problem, the domain is solved either using an axisymmetric two-dimensional model, a

quarter of the domain, or a slice ("piece of cake") of the reservoir, depending on the computational resources and the specifications of each software.

The second benchmark test extends the scope of the first test by considering non-isothermal effects resulting from cold CO_2 injection in both the reservoir and the caprock. Since caprock integrity is an important parameter. The third example addresses the geomechanical effects induced by the CO_2 injection.

Simulation results show that all codes can solve the highly coupled non-linear system of partial differential equations and they are in fairly good agreement with each other. Yet, differences arise for some parameters. The sources of errors come from differences in the equations of state of brine and CO_2, in the discretization methods, or implementation. By conducting a series of result inter-comparison sessions, the groups were able to improve the quality of results and identify errors.

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