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Multiphysics in time and space for the simulation of CO_2 storage in deep saline aquifers

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One of the currently investigated options to mitigate greenhouse gas emissions is Carbon Capture and Storage (CCS). A crucial step for the application of this technology is finding suitable and safe storage sites. Apart from the constraint of technical and economical feasibility, the CO_2 storage project needs to gain public acceptance. Comprehensive site investigations and a reliable risk assessment are therefore key points for the realisation of a CO_2 storage project. To meet these requirements detailed numerical simulations are essential.

Numerical simulations that accompany a CO_2 storage project need to cover the whole complexity of relevant physical processes. Apart from nonisothermal multiphase flow and transport processes, geomechanical and geochemical processes might need to be taken into account. Moreover, large scale effects like regional pressure build up and induced brine migration might play a role. Finally, the long-term fate of the CO_2 plume and the ultimate trapping of the injected CO_2 need to be determined. Tools that are capable of describing the whole complexity of relevant physical and chemical processes are rare and the required temporal and spatial scales lead to high computational costs.

One way to increase model capability and efficiency is to couple models of different complexity. On the one hand, model coupling can be applied to include the description of processes that are not covered by a standard multiphase flow and transport simulator. On the other hand, coupling models of different complexity increases model efficiency since it allows to apply the models according to the temporal and spatial changes of dominating physical processes, instead of using a full complexity model for the whole simulation time and for the entire model domain.

Here the focus lies on model coupling as a measure to increase model efficiency. Two types of model coupling will be presented, namely, sequential model coupling (multiphysics in time) and spatial model coupling (multiphysics in space).

An example for multiphysics in time is the application of a nonisothermal two-phase model that neglects compositional processes during the injection period and the switch to a nonisothermal two-phase, two-component model in the post injection period. The application of the model with reduced complexity on the short timescale is motivated by the fact that during the injection period nonisothermal, advection and buoyancy driven processes dominate, while compositional processes like CO_2 dissolution and diffusion gain importance in the post-injection period. Another application for sequential model coupling, which will also be presented, is the switch to an isothermal model on the large timescale, when nonisothermal effects do not play a role anymore. Multiphysics in space means that the model domain is split up into two or more subdomains, where different models are applied. Thus, a subdomain close to the injection well, where the pressure build up reaches a certain threshold value and geomechanical processes might play a role, can be coupled to a second subdomain farther away from the injection well, where only two-phase or even single-phase flow and transport processes (brine migration) need to be taken into account.

For an efficient application of these coupling schemes, it is important to find suitable coupling conditions for the model interfaces in time and space. Moreover, coupling criteria need to be determined for an optimal realisation of the presented coupling schemes.