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Development and application of a coupled ECLIPSE – GeoSys modelling system for simulation of CO2 storage in saline aquifers

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The storage of CO2 in deep saline aquifers is due to the large available capacities and the common occurrence of these formations one of the major options for carbon dioxide sequestration. Though the injection of CO2 is tested at some places like the Sleipner field or the Snohvit field the system and its short and long-term reactions are currently not well enough understood. Besides the multiphase flow aspects geochemical, thermal and mechanical processes may alter the conditions within the reservoir as well as in the cap rock. The CO2 rich brine has a potential of mineral dissolution due to the acidic conditions that might be followed by mineral precipitation again. Mineral dissolution and precipitation affects the porosity and permeability and thus feeds back on multiphase flow. The geochemical reactions depend on the thermal conditions in the saline aquifer as well as on the pressure. Whereas single aspects of these processes can be investigated with experiments their combined consequences for the behaviour of the storage system can only be evaluated with a multi-processes simulator over short and long time scales.
The open-source scientific software OpenGeoSys (OGS) was used in this investigation to simulate CO2 injection into a saline formation. To represent the hydraulic and geochemical alteration during CO2 sequestration under reservoir conditions, OGS was coupled to the widely used multiphase flow simulator ECLIPSE for modelling multiphase flow and to CHEMAPP for geochemical equilibrium reactions. CHEMAPP is well applicable under high pressure and salinity conditions as they occur during storage of CO2.
ECLIPSE and OGS are coupled using an operator splitting approach. Results of the multiphase flow simulation are passed for each time step from ECLIPSE to OGS where transport of dissolved species is calculated. Subsequently equilibrium and kinetic reactions at each node of the OGS FEM model might be simulated. Changes in the permeability and porosity induced by these geochemical reactions will be transferred back to the multiphase simulator. Transport of components might be considered in the CO2 as well as in the water phase.
This paper will present the coupled OGS-ECLIPSE software and its successful application to several benchmarks for validating the code coupling. Furthermore the comparability of multiphase flow and component transport results for the simulators OGS, DuMux and ECLIPSE is investigated. All three codes use different numerical methods for solving the partial differential equations. Furthermore ECLIPSE as well as DuMux use an upwinding scheme that further damp the results compared to OGS. Thus the benchmarks show a high sensitivity of the CO2 saturation on the vertical model resolution due to the buoyancy effect.
Finally, an application of the software for simulating CO2 injection for a hypothetical CO2 reservoir in the north German basin will be presented. The main focus of the simulations is the evaluation of the long term geochemical changes induced and their feedback on the multiphase flow field. These changes are evaluated considering the target storage formation as well as the cap rock.
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