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Upscaled modeling of CO_2 injection with coupled thermal processes

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Large-scale models of CO_2 storage in geological formations must capture the relevant physical, chemical and thermodynamical processes that affect the migration and ultimate fate of injected CO_2. These processes should be modeled over the appropriate length and time scales. Some important mechanisms include convection-driven dissolution, caprock roughness, and local capillary effects, all of which can impact the direction and speed of the plume as well as long-term trapping efficiency. In addition, CO_2 can be injected at a different temperature than reservoir conditions, leading to significant density variation within the plume over space and time. This impacts buoyancy and migration patterns, which becomes particularly important for injection sites with temperature and pressure conditions near the critical point. Therefore, coupling thermal processes with fluid flow should be considered in order to correctly capture plume migration and trapping within the reservoir.

A practical modeling approach for CO_2 storage over relatively large length and time scales is the vertical-equilibrium model, which solves partially integrated conservation equations for flow in two lateral dimensions. We couple heat transfer within the vertical equilibrium framework for fluid flow, focusing on the thermal processes that most impact the CO_2 plume. We investigate a simplified representation of heat exchange between the plume and the reservoir that also includes transport of heat within the plume. In addition, we explore CO_2 thermodynamic models for reliable prediction of density under different injection pressures, temperatures and composition. The model concept is demonstrated on simple systems and applied to a realistic storage aquifer.