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ON THE LONG-TERM EVOLUTION OF A CO_2 PLUME UNDER A SLOPING CAPROCK

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Summary. Large potential for CO_2 geologic storage exists in sedimentary basins in which saline aquifers and associated caprock formations have significant slope that persists on regional scales. Important examples include the Carrizo-Wilcox aquifer in the Texas Gulf Coast Basin, the Mt. Simon aquifer in the Illinois Basin, and saline aquifers in the Alberta Basin, Canada. Understanding the long-term fate of CO_2 stored in an aquifer with a sloping caprock is of great practical interest, and is very challenging due to the importance of processes that operate on a broad range of space and time scales.

This paper presents numerical simulation studies that explore flow mechanisms affecting CO_2 plume behavior and its dependence on problem parameters. We find that the mechanism of plume advance is different from what is seen in a forced immiscible displacement, such as gas injection into a water-saturated medium. Instead of pushing the water forward, the plume advances because the vertical pressure gradients within the plume are smaller than hydrostatic, causing the water column to collapse at the plume tip. Gas saturations and updip CO_2 fluxes are nearly constant, independent of time and position, in the upper, mobile portions of the plume. The CO_2 plume becomes thinner as it advances, yet the speed of advancement remains constant over the entire simulation period of up to 400 years, with migration distances of more than 80 km. Our simulation includes dissolution of CO_2 into the aqueous phase and associated density increase, and molecular diffusion. However, no convection develops in the aqueous phase because it is suppressed by the relatively coarse (sub-)horizontal gridding required in a regional-scale model. A first crude sub-grid-scale model was implemented to represent convective enhancement of CO_2 dissolution. This process is found to greatly reduce the thickness of the CO_2 plume, but does not affect the speed of plume advancement.