Analysis of Buoyancy Driven Miscible Convection in Heterogeneous Saline Aquifers

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Dissolution of supercritical CO2 into the brine across the CO2-brine interface increases the density of the CO2-in-brine solution compared to the density of the underlying pure brine. The resulting unstable density stratification leads to the amplification of perturbations at the CO2-brine interface. In a homogeneous aquifer, the perturbation amplification follows a finite, but usually short, period of decaying disturbances. The details of this buoyancy driven instability are not yet known for heterogeneous (spatial variations in permeability). We perform a stability analysis of interfacial perturbations for heterogeneous aquifers. We study the interactions between the characteristic length scales associated with both diffusion and permeability heterogeneity. Moreover, we investigate the potential harmonic excitation of the homogeneous solution by heterogeneity induced forcing. We show that unlike other interfacial stability problems in porous media, the gravitational convection problem in saline aquifers does not possess a particular solution even in the presence of external forcing due to heterogeneity. This feature necessitates a wider analysis of the generalized problem in order to classify the parameter space comprised of a Rayleigh number and the heterogeneity characteristics with respect to harmonic amplification of homogeneous modes. The nonlinear evolution and interactions of the unstable modes for long times are also studied using high-accuracy spectral simulations.