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Rayleigh-Bénard instability in heterogeneous porous media

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Convective mixing is present in a large assortment of natural and industrial processes, such as in carbon capture and sequestration, where it ensures a safer storage of carbon dioxide, seawater intrusion, high-level radioactive waste disposal sites and geothermal energy production. In this work, we study the effect of the heterogeneity on the behavior of convective mixing since most of the works that have been conducted so far did not take heterogeneity into consideration.

To do so, we consider the Horton-Rogers-Lapwood problem where convection is triggered by a Rayleigh-Bénard instability. Heterogeneity is represented by 2-D multi-Gaussian log-Normally distributed anisotropic permeability fields. We perform a parametric study in which we explore the effect of the variation of the Rayleigh number (Ra), the variance and the correlation length of the permeability field on the fingering patterns, mixing and dissolution fluxes. Mixing is characterized by the scalar dissipation rate and the boundary fluxes. The mixing state is evaluated through the probability density function of the concentration and the intensity of segregation. We show the difference in behavior between the dissolution fluxes and the mixing state both for the case of homogeneous and heterogeneous porous media. We observe that convective mixing is enhanced in the case of heterogeneous porous media compared to the homogeneous counterparts.
An increase of Ra causes a more rapid homogenization of the system especially for the heterogeneous case. For permeability fields with a small correlation length, the effect of the heterogeneity is substantial only for a variance higher than 2. However, for a larger correlation length, this effect is more pronounced and the fingering patterns are no longer smooth but dispersive.

Based on these observations, an upscaling of the model based on the effective longitudinal and transverse permeability and the dispersion coefficient is performed.

Key words: convective mixing, Rayleigh-Bénard instability, heterogeneity, scalar dissipation rate, dissolution fluxes.

Participation

In-Person

References

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Primary authors: Ms BENHAMMADI, Rima (IDAEA-CSIC); Dr HIDALGO, Juan José (IDAEA-CSIC); Prof. DENTZ, Marco (IDAEA-CSIC)

Presenter: Ms BENHAMMADI, Rima (IDAEA-CSIC)

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