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CO₂ convective dissolution controlled by temporal changes in free-phase CO₂ properties

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Understanding the factors that control CO₂ convective dissolution, which is one of the permanent trapping mechanisms, in the deep saline aquifer and associated dynamics of mixing is crucial in the long-term fate of the injected CO₂. The present study investigates the effects of temporal changes in the solubility of CO₂ at the free-phase CO₂/brine interface on the onset of natural convection and the subsequent convective mixing by conducting linear stability analyses (LSA) and direct numerical simulations (DNS). A time-dependent concentration boundary is considered for the free-phase CO₂/brine interface where the CO₂ concentration first decreases with the time and then remains constant. The LSA results show that the temporal variation in the concentration increases the onset of natural convection up to two orders of magnitude. In other words, size and pressure of the injected CO₂ affect the commencement of convective mixing. Based on LSA results, several scaling relations are proposed to correlate critical time and its corresponding wavenumbers with time-dependent boundary's parameters, such as concentration decline rate and equilibrium concentration ratio. The DNS results reveal that the convective fingering patterns are significantly influenced by the variation of CO₂ concentration at the interface. These findings improve our understanding of CO₂ solubility trapping and are particularly important in estimation of potential storage capacity, risk assessment, and storage sites characterization and screening.

References

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Primary authors: JAFARI RAAD, Seyed Mostafa (PhD); EMAMI-MEYBODI, Hamid (Pennsylvania State University); HASSANZADEH, Hassan (University of Calgary)

Presenter: EMAMI-MEYBODI, Hamid (Pennsylvania State University)

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