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Onset of nonlinear convection in transient diffusive boundary layers: application to CO_2 sequestration NILS TILTON, AMIR RIAZ, University of Maryland, College Park — The linear stability of transient diffusive boundary layers in porous media has been studied extensively for applications to carbon dioxide sequestration. The onset of nonlinear convection, however, remains understudied because the transient base-state invalidates traditional weakly nonlinear stability methods. We study the onset of nonlinear convection using complementary asymptotic expansions and high-order direct numerical simulations (DNS). We first demonstrate by DNS that when a boundary layer is perturbed with a single Fourier mode, nonlinear mechanisms generate a zero-wavenumber response that becomes equal-order with the fundamental mode after the onset of nonlinear convection. This invalidates traditional weakly nonlinear methods that assume the zero-wavenumber response is small. Nevertheless, we demonstrate that the initial onset time of nonlinear convection can be accurately determined from a regular asymptotic expansion that is two orders-of-magnitude faster than DNS. Using the expansion, we find there is an optimal perturbation wavenumber and initial perturbation time that minimize the onset time of nonlinear convection. We obtain analytical relationships for these optimal parameters in terms of typical aquifer properties and initial perturbation magnitude.

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