Convection in coupled fluid-porous media systems

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In superposed fluid-porous media systems, the ratio of the fluid height to the porous medium height exerts a significant influence on the behavior of the coupled system, most notably with its impact on resulting convection cells. Altering the depth ratio slightly can trigger a transition from full-convection where convection cells extent throughout the entire domain to fluid-dominated convection where cells occupy only the fluid region. With current interest surrounding superposed fluid-porous medium systems in numerous projects of industrial, environmental, and geophysical importance (oil recovery, carbon dioxide sequestration, contamination in sub-soil reservoirs, etc.), being able to predict the critical depth ratio where this convection shift occurs is particularly timely. Based on the critical Rayleigh numbers of the respective uncoupled domains, we propose a theory for predicting the depth ratio required for the transition from full- to fluid-dominated convection. With results from stability analyses and numerical simulations, we find good agreement between critical predicted depth ratios and actual values, especially in the small Darcy number limit.