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Using Homogenization Theory to Study Convection in Thermohaline Systems

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We study a density-driven system in which the density gradients arise from salinity and temperature differences. Since the solute and heat diffuse at different rates, such systems are also called *double-diffusive* and arise in many practical applications like carbon dioxide sequestration, geothermal energy exploitation and the storage of nuclear and normal waste in geological formations. A typical sedimentary-basin set-up is adopted where both salinity and temperature increase with depth. In such systems, the buoyancy forces caused by salinity and temperature gradients give rise to counter-acting convection cells. The homogenization theory ideas originally developed in Held et al. (2005) are applied to the solute and heat transport equations and the two resulting cell problems solved coupled. A dimensionless number is derived from the solutions to the cell problems in terms of the physical variables temperature, viscosity and density contrasts; gravity-driven velocity, domain size and formation hydrogeological properties. The sign of the number changes to negative when the thermal-convection predominates over solutal-convection. The derived dimensionless number is tested against numerical simulations performed with the software package d^3f on sufficiently refined grids that deliver stable numerical solutions without upwind techniques (Frolkovic and De Schepper, 2001). We also investigate the possibility of groundwater intrusion into a geological formation by applying a horizontal drift at the top of the domain. The evolution of fingers in haline density-driven systems was studied e.g. in Musuuza et al. (2009) and such a velocity aligned orthogonal to the direction of finger propagation was found to retard finger growth.

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