Numerical simulation of the genesis of superhighway convection in a slightly inclined layer of a binary liquid mixture

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Convection in a fluid layer is affected by its orientation with respect to the gravitational field. In the present work, we investigate numerically pattern selection in a vertical cylindrical cell heated from below for positive Soret coefficient mixtures and analyse the effect of marginal inclinations of gravity in pattern formation.

The dynamics of mixtures with a positive value of the Soret coefficient without inclination has essentially been studied in laboratory experiments [1, 2, 3], and numerical simulations reduce to periodic domains [4, 5]. According to these studies, close to convective onset, the motion is dominated by the solute gradient, and a stationary square pattern with negligible change in heat transport is reached (Soret regime). Far from threshold, convection selects the usual roll structure observed in pure fluid convection, where a strong change in heat transport takes place. In the crossover region, a cross roll regime is observed and the competition between square and roll patterns leads to oscillations.

![Figure 1: (Left) Stationary square pattern obtained in a non-inclined cylinder of aspect ratio $\Gamma = \frac{R}{h} = 10$. (Right) Its progressive destruction due to the establishment of the large scale flow when a slight inclination of $\alpha = 0.024$ rad is introduced. As reference values for the parameters, we consider those used in the experiment of [6] (Separation ratio $S = 0.13$, Lewis number $\tau = 0.011$ and Prandtl number $\sigma = 10$).](image)

Interestingly, positive Soret coefficient mixtures have been used in the recent experimental work of Croccolo et al [6] to investigate the effect of inclination of the layer on the long-term stability. At small Rayleigh numbers, the mass transfer is dominated by the induced large scale shear flow, while at larger Rayleigh numbers, it is dominated by solutal convection. Unexpected results are reported at the transition: drifting columnar flows moving in opposite directions along parallel lanes in a superhighway configuration have been observed.

We will present simulations corresponding to both non-inclined and inclined cells. In particular, we have been able to obtain numerically superhighway convection (SHC). The numerical analysis should shed some light on the origin of these fast drifting columnar flows observed in experiments.
Figure 2: Superhighway convection (SHC) observed in a $\Gamma = \frac{R}{h} = 5$ cell inclined $\alpha = 0.024$ rad. Vertical velocity is plotted. (Rayleigh number $R = 1590$, Separation ratio $S = 0.13$, Lewis number $\tau = 0.011$ and Prandtl number $\sigma = 10$).

References


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