Onset of Convection in Supercritical Fluids

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The prediction of the onset of convection in a supercritical fluid layer has been the object of a renewed interest in recent years, with the publication of experimental, theoretical and numerical works on this subject by several teams worldwide. Convection in supercritical fluids is specific due to the existence of a fourth mode of heat transfer in these fluids, the Piston Effect. Couplings between this effect and the processes leading to the onset of convection induce very peculiar and unexpected phenomena. In the present work, we conduct a theoretical analysis of the problem of the Rayleigh-Benard instability of a supercritical fluid layer, and confront its predictions to recent experimental results.

The fluid layer considered here is subjected to a bottom heating through a prescribed heat flux, while its top boundary is maintained at a constant temperature. The dispersion relationship of the instability process is constructed analytically using asymptotic methods and classical linear stability analysis. The associated generalized boundary values problem is then solved numerically. The results that are obtained allow us to: (i) determine if a given fluid layer subjected to a given bottom heat flux is stable or unstable versus convection; (ii) predict the time it takes for convection to ensue once the heat flux has been turned on; (iii) predict the global morphology of the fluid flow shortly after the onset of convection.

The predictions of our model are then compared to experimental data recently obtained by Kogan and Meyer [1] and a very good match is observed, which confirms validity of the method. In a previous work [2], we demonstrated that convection in a near-critical fluid layers could ensue following four different scenarios. Here we conduct a systematic parametric analysis in order to build a two-dimensional "phase diagram", indicating which convection scenario takes place as a function of the bottom heat flux and reduced temperature. This phase diagram is, again, discussed in relation to the experimental results of Kogan and Meyer.

[1] Kogan et al, *PRL* **82** (1999).
[2] L. El Khouri and P. Carles, *PRE* **66** (2002).