Rayleigh-Bénard convection interacting with a melting boundary

J. Purseed[1], B. Favier[1] & L. Duchemin[1]

Aix-Marseille Université, CNRS, École Centrale Marseille, IRPHE UMR 7342, Marseille, France
jhaswantsing.PURSEED@univ-amu.fr

We study the evolution of a melting front between the solid and liquid phases of a pure incompressible material where fluid motion is driven by unstable temperature gradients. In a plane layer geometry, this can be seen as classical Rayleigh-Bénard convection, where the upper solid boundary is allowed to melt due to the heat flux brought by the fluid underneath (see [2]). This free-boundary problem is studied numerically in two dimensions using a phase-field approach, which we dynamically couple with the Navier–Stokes equations under the Boussinesq approximation. We focus on the case where the solid is initially nearly isothermal, so that the evolution of the topography is related to the inhomogeneous heat flux from thermal convection, and does not depend on the conduction problem in the solid. From a very thin stable layer of fluid, convection cells appear as the depth (and therefore the Rayleigh number) of the layer increases. As predicted by Vasil and Proctor [1], we confirm that the Stefan condition changes the onset for convection. In the supercritical regime, the continuous melting of the solid leads to dynamical transitions between different convective cell sizes and topography amplitudes. The Nusselt number can be larger than its reference value for a flat upper boundary due to the feedback of the topography on the flow, which can stabilize large-scale laminar convective cells.

Références

1. G. M. Vasil and M. R. E. Proctor. Dynamic bifurcations and pattern formation in melting-boundary convection. *J. Fluid Mech.* (2011), *vol.* 686, *pp.* 77-108
2. S. H. Davis, U. Müller and C . Dietsche. Pattern selection in single-component systems coupling Bénard convection and solidification. *J. Fluid Mech.* (1984), *vol.* 144, *pp.* 133-151