HETEROGENEOUS MANTLE CONVECTION IN A MICROWAVE OVEN

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The pattern of convection in Earth′s mantle is still controversial because of conflicting evidence from geophysics and geochemistry: seismic tomography reveals slabs reaching the bottom of the mantle, arguments in favor of whole mantle convection and mixing while chemical composition of erupted magma requires distinct reservoirs with different isotopic composition. The origin and the dynamics of these reservoirs, as well as their contribution to the global thermo-chemical evolution of the Earth, are the objects of intense debates. The reservoirs can be pristine or due to the progressive accumulation of material subducted from the surface of the Earth. In the two cases, the question of the stability of the reservoirs at a geological time scale is central. To study the stability of such reservoirs in the context of vigorous mantle convection, we carry out two-layer experiments in which the bottom layer contains a higher amount of internal heating. For this purpose we have devised a new technology based on microwave heating, validated in previous studies [1]. A deeply modified microwave oven contains the experimental tank that accommodates the experimental fluids. A laser sheet scans the tank and two cameras acquire images in different spectral zones using adequate colour filters. The temperature is measured using laser-induced fluorescence while the 2D velocity field is measured using particle image velocimetry. The dimensionless numbers characterizing two-layer convection are: the depth layer ratio, d_1/d, the internal heating ratio, H_1/H_2, the viscosity ratio, γ, the buoyancy number, B_0 (the ratio of the stabilizing density anomaly to the destabilizing thermal anomaly), and the Rayleigh-Roberts number Ra_H describing the vigor of convection in each layer. Fig. 1 shows an example of a heterogeneous experiment with d_1/d=0.28, H_1/H_2=8, γ=0.7, B_0=0.9, Ra_{H1}=424 and Ra_{H2}=4500. Experiments are performed for a wide range of parameters to obtain stability diagrams giving the regime of convection as a function of dimensionless parameters. These diagrams indicate that even a highly stratified (B_0>1), low viscosity (γ<1) bottom layer ends up in piles. Piles eventually de-stabilize if the depth layer ratio exceeds a certain value. For high viscosity (γ>1) bottom layer we observed a stratified, two-layer convection with oscillating interface if the buoyancy number, B_0, exceeds a certain value.
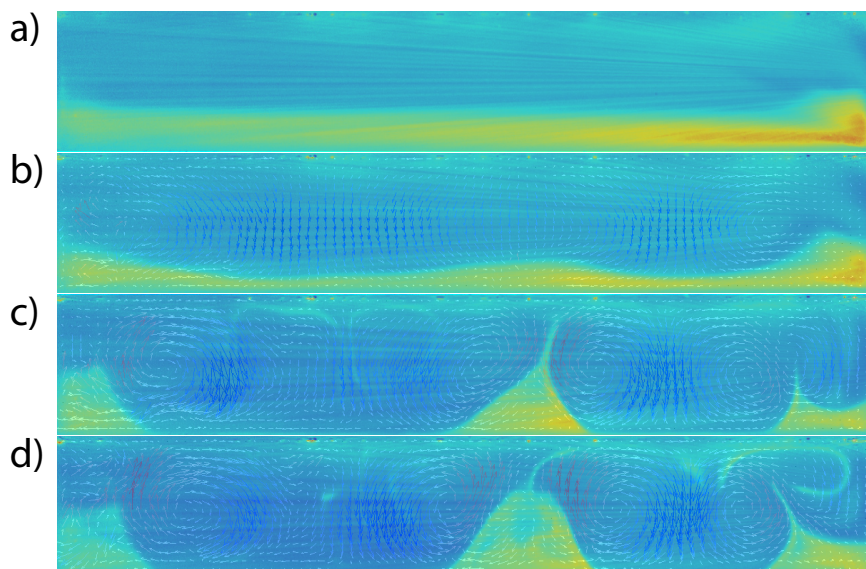
Figure 1. Cross-section of the experimental tank containing the optical image superposed on the 2D velocity field a) initial, stable condition, b) initiation of convection into the top layer, c,d) pile formation and tendril entrainment.

References

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