# NUMERICAL SIMULATIONS OF RAYLEIGH-BENARD SYSTEMS WITH NON-HOMOGENEOUS THERMAL BOUNDARY CONDITIONS

Ripesi Patrizio[1], Biferale Luca [1], Sbragaglia Mauro [1] & Achim Wirth [2]
[1]*Department of Physics and INFN, University of Rome Tor Vergata*
[2]*MEIGE/ LEGI /CNRS Grenoble (France)*

*Abstract* In this work we present a study of 2D thermal Rayleigh-Benard systems with non-homogeneous boundary conditions. For this kind of system we investigated the static solution and the transition to bulk convection using both an analitical and a numerical approach. Results from numerical simulations are presented to show the behavior under fully turbulent conditions. The effect of strength of the forcing and the size of the inhomogeneity elements, varied between experiments, is determined.

## PHYSICAL SYSTEM

Thermal Rayleigh-Benard (RB) convection [1] is common in a variety of dynamical systems and has applications spanning from astrophysics to atmospheric and ocean physics [2] down to small scale engineering applications. The classic RB system consists of a fluid subject to an external gravity field $g$ placed between two plates, heated from below and cooled from above. The associated thermal dynamics is usually characterized by the Rayleigh number ($Ra = \frac{g\alpha\Delta T H^3}{\nu k}$), where $H$ is the distance between the plates, $\alpha$, $k$ and $\nu$ are the thermal expansion, the diffusivity coefficients and the kinematic viscosity of the fluid. The system is linearly unstable and bulk convection starts above a critical Rayleigh number $Ra > Ra_c$, the latter being determined by the fluid properties and boundary conditions of the system. Highly chaotic dynamics develops at increasing $Ra$, reaching fully turbulent convection for $Ra \sim 10^8$ and higher.

In nature we can find a great variety of RB systems in which the temperature sources present an irregular or non-

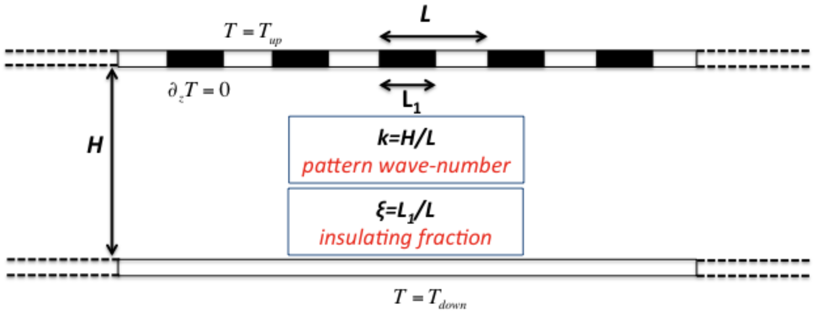


**Figure 1.** The sketch of the periodic cell with mixed temperature boundary conditions in the upper wall.

homogeneous pattern, as for example the case of sea-ice insulating effect on the ocean or the continental insulating effect on the Earth mantle convection. For this kind of system, we studied [3] the onset of *bulk* convection in a RB cell with the upper wall consisting of a periodic sequence of insulating ($\partial_z T = 0$ ) and cooled ($T = Tup$) patches (Fig. 1). The transition from the presence of only a localized convective region at the upper plate to a bulk convection across the whole volume is characterized in terms of a critical Rayleigh number ($Ra_c$) which depends on the strength and the inhomogenity of the forcing. The properties of the pattern can be described by two dimensionless control parameter, i.e. the pattern wave-number defined as the ratio between plate distance and the sum of the length of the insulating and conducting lids (referred as $k = H/L$) and the insulating fraction $\xi = L_1/L$. Our theory is confirmed by numerical simulations performed with a Thermal Lattice Boltzmann (LB) numerical scheme [4]. Numerical and analytical values of $Ra_c$ are in good agreement for range of pattern wave-numbers where a perturbative calculation is possible. Finally, results in the fully turbulent regime are presented, showing that when the scale of the roughness elements falls below the boundary layer thickness the system behaves like the classic (i.e. with homogeneous boundary conditions) RB case.

## References

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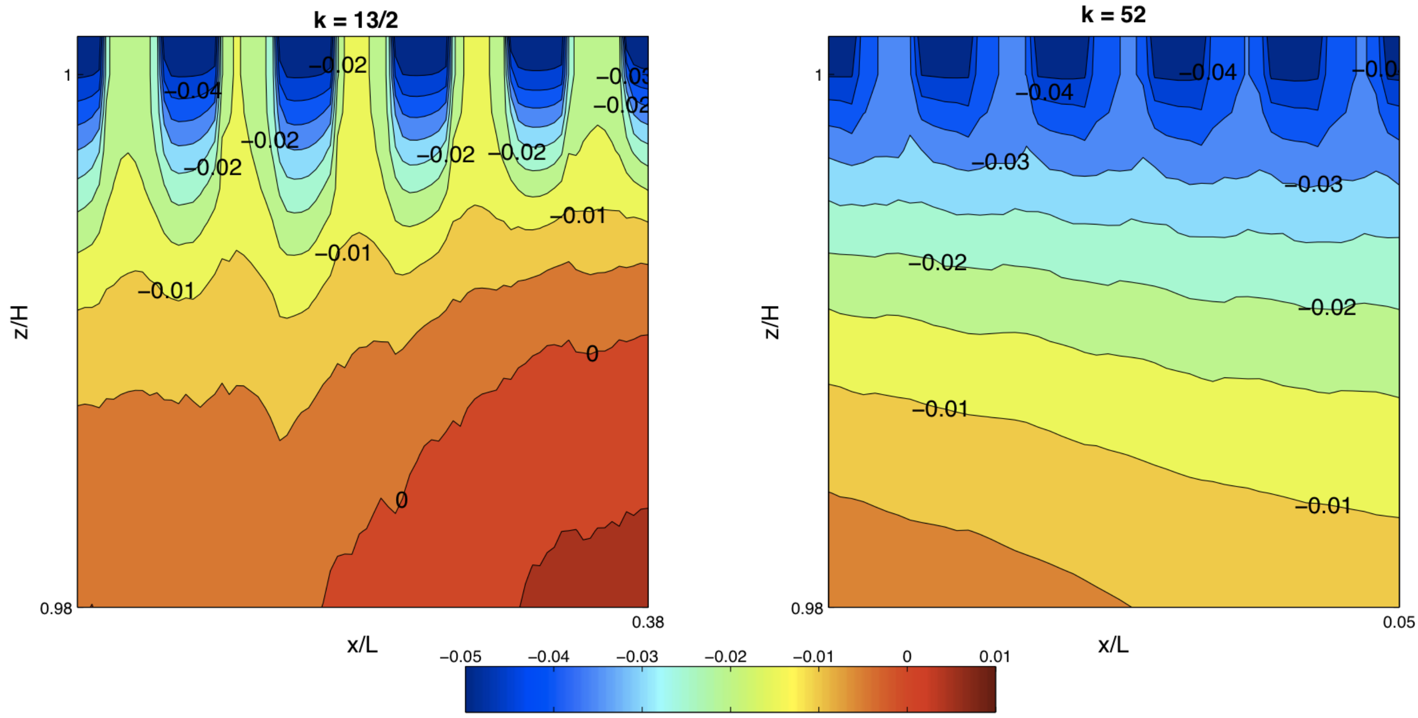


**Figure 2.** Upper boundary temperature pattern for two different values of $k = H/L$ (the ratio among the distance between the two walls and the typical lenght-scale of the upper non-homogeneous pattern (see Fig.1)) at $Ra = 2 \times 10^9$.