Small coherent structures in rough turbulent convection

Nathan Carbonneau[1], Julien Salort[2], Anne Sergent[1]

[1] Lab. Interdisciplinaire des Sciences du Numérique, Université Paris-Saclay, CNRS, Orsay, France
[2] Lab. Physique, Ecole Normale Supérieure de Lyon, CNRS, Lyon, France
nathan.carbonneau@lisn.fr

Turbulent convection is a spontaneous physical process present in natural environments as well as in many industrial systems. However, most of these systems are not ideal in terms of underlying surfaces and involve specific topography or small-scale roughness. Interactions between plate roughness and nearby flow can induce changes in turbulence scales [1]. In addition, when the flow is confined by the side walls of a cavity, or when it is enclosed by two large-scale horizontal walls, a large-scale circulation (LSC) is established in the fluid volume [2]. The aim of this work is to reveal how the LSC changes small flow structures by considering either a cavity flow or a fluid layer of reduced size, in particular when a plate is rough.

In this study we consider three types of bottom plates : smooth plate, and two plates with evenly distributed roughness elements (different heights, same aspect ratio and same spatial distribution). Three confined cavities and three periodic fluid domains are modelled by means of direct numerical simulations at constant Ra and Pr, considering the different types of plates as indicated above.

We explore the effect of roughness elements on the flow structure at different scales by comparing the rough cases to the smooth ones. Furthermore, the effect of the LSC on the turbulent structures is investigated by comparing closed and periodic configurations for each bottom wall type. For example, in the case of a smooth plate, it appears that the size of the small-scale thermal structures is altered by the LSC. As shown below (figure 1), the presence of the LSC contributes to enlarge the coherent thermal structures.

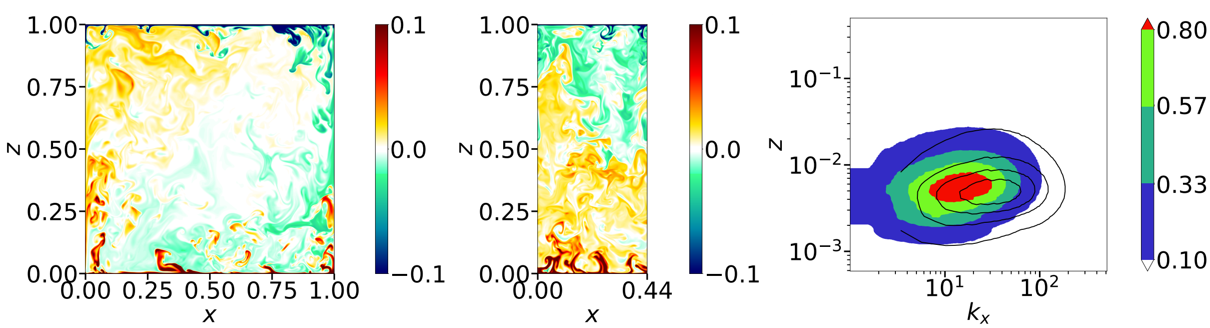

Figure 1. Comparison for the smooth case of two mid-depth temperature snapshots : confined cavity (left) and periodic layer (middle). The colormap is centered on the bulk temperature of the closed cavity $T_{bulk} = 0.5$. The difference of the thermal structure size is illustrated by the horizontal Fourier transform (in x direction) performed at all altitudes z on the temperature fluctuation field $T' = T - < T >_t$ (right). The colors correspond to the complete cavity while the lines correspond to the periodic case.

Références

1. Liot et al., *Phys. Rev. Fluids*, **2**, 044605 (2017).
2. Blass et al., *J. Fluid Mech.*, **906**, A26 (2021).