LAGRANGIAN MEASUREMENTS OF TEMPERATURE AND VELOCITY IN TURBULENT THERMAL CONVECTION

O. Liot, F. Seychelles, J. Salort, E. Rusaouen, M. Tanase, F. Chillá, B. Castaing, Y. Gasteuil, J.-F. Pinton
Laboratoire de Physique ENS Lyon,CNRS, PRES Univ. de Lyon

The understanding of organization of the heat flux transport in turbulent Rayleigh Bénard convection is still a challenge. From the experimental point of view the large majority of works concerns the measure of the global integrated quantity $Nu = QH/\lambda\Delta T$ as function of the control parameter $Ra = \frac{g\alpha\Delta T H^3}{\nu\kappa}$. Some attempts to characterize the statistics and the local heat flux with local fixed probes have been done in [1] : they show very strong non gaussian non symmetric behavior. To well understand mixing and the role of the large scale structures that carry the temperature the best will be to follow the flow during its motion as it is done in atmospheric flows. The first measures in a laboratory experiment have been shown in [2] in which an instrumented particle, known now as "Smart Particle", able to locally measure temperature, was introduced in a Rayleigh-Bénard cell. This measurement realized at $Ra = 10^{10}$ showed the first lagrangian spectra of temperature and velocity in Rayleigh-Bénard convection. We report in this work new measurements performed with the same kind of particle which has an improved electrical circuit that allows for longer time measurements (about 300 turn over times). We use the same rectangular vessel with height $H = 40cm$ and section of $40 \times 10cm^2$ filled with water. The walls are made of polymethylmetacrylate (PMMA), the top boundary is a copper plate chilled by a controlled water bath, and the bottom boundary is an electrically heated copper plate. The mobile sensor consists of a $D = 21mm$ diameter capsule containing temperature instrumentation, an rf emitter, and a battery. It is described in detail in [3]. The capsule and fluid density are carefully matched within 0.05% so that it reliably follows the flow. Four thermistors ($0.8mm$ $230K\Omega$, response time $0.06s$ in water) are mounted in the capsule wall protruding $0.5mm$ into the surrounding flow. A resistance controlled oscillator is used to create a square wave whose frequency depends on the temperature of the thermistors. This square wave is used directly to modulate the amplitude of the radio wave generated by the rf emitter. The temperature signal is recovered on the fly by a stationary receiver. The capsule have been redesigned in order to have the 4 thermistors at the equator, a simpler handling and to put inside two batteries to extend the emission time. At the same time the particle trajectory is unregistered with a digital camera as shown in figure 1 where are reported the particle trajectories with the map color indicating the temperature measured by the particle. It is so possible to obtain the

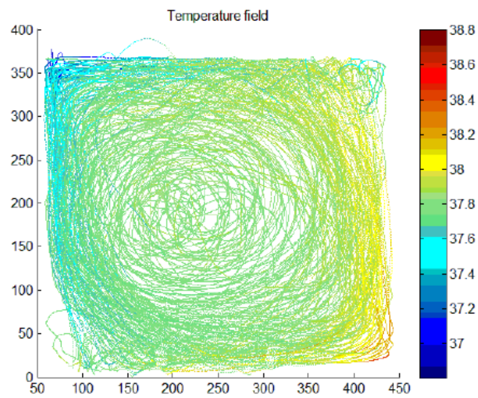

Figure 1. Trajectories of the particle for the whole measurement at $P = 200W$, $Ra = 310^{10}$

velocity by successive derivation. We perform the measurements at 3 different powers $P = 200W, 300W, 400W$ at which correspond the following Rayleigh numbers $Ra = 310^{10}$, $Ra = 410^{10}$, $Ra = 510^{10}$. The mean temperature is fixed at $38.5°C$ and so the Prandtl number is $Pr = 4$. The velocity power spectra for the 3 measurements show 3 a scaling range close to f^{-2}, as expected for a Lagrangian tracer in a turbulent flow (however scaling range is limited at such $R_\lambda \sim 100$). The particle probes the temperature all over the flow excepted the boundary layers which are too thin (about 600μ) in these

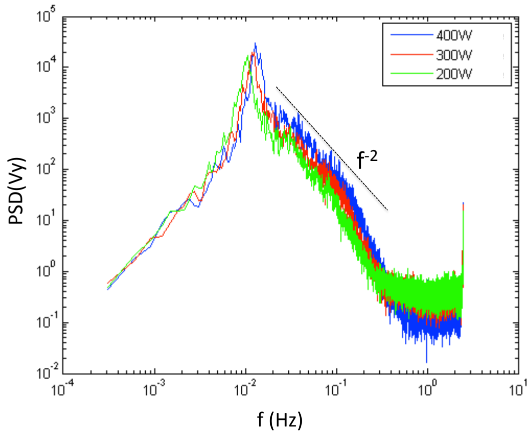

Figure 2. Power density spectrum of vertical velocity

working conditions. The probability density functions of temperature are clearly non gaussian while the power density spectra exhibit a scaling close to $f^{-2.5}$ which seems to indicate that temperature is not a passive scalar and probably dominated by the large scale flow behavior.

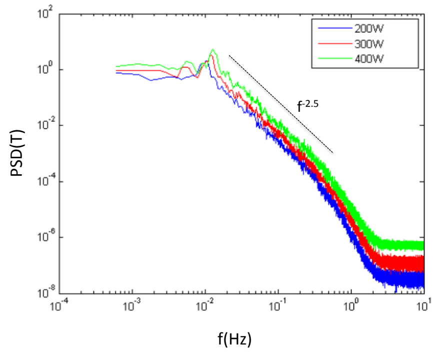

Figure 3. Lagrangian power density spectrum of temperature

References

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[3] W. Shew et al., Rev. Sci. Instrum. 78, 065105 (2007).