LOCAL BOUNDARY LAYER HEAT TRANSPORT IN TURBULENT RAYLEIGH-BÉNARD CONVECTION

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Abstract We discuss the ratio between diffusive and convective heat transport in turbulent Rayleigh-Bénard (RB) convection in air. In particular, we focus on the flow region close to the lower surface of the cooling plate often referred to as boundary layers. By measuring the wall-normal velocity component and the temperature simultaneously at various distances from the plate surface profiles of the diffusive and the convective fraction $\dot{q}_d(z) = -\lambda \partial T/\partial z$ and $\dot{q}_c(z) = c_p \rho \langle v_z{}'T' \rangle$ of the total heat flux throughout the boundary layers have been obtained. The measurements have been undertaken in the large-scale Rayleigh-Bénard experiment "Barrel of Ilmenau" and they cover various Rayleigh numbers as well as representative locations with respect to the mean wind.

Rayleigh-Bénard (RB) convection - a fluid layer of a depth H heated from below and cooled from above - represents a great variety of natural and technical flow phenomena. One of the keys to understand the global heat transport between the heated bottom and the cooled top plate is the mechanism of the heat transport throughout the fluid layers adjacent to the horizontal plates commonly referred to as boundary layers. Over the last decades a physical picture has been established that this transport can be considered as a diffusive process below a critical Rayleigh number Ra_c while it becomes of convective nature above this bound [1]. However, there is neither a consensus about the value of Ra_c nor the process itself is well understood.

We have measured the diffusive and the convective fractions $\dot{q}_d(z) = -\lambda \partial T/\partial z$ and $\dot{q}_c(z) = c_p \rho \langle v_z{}'T' \rangle$ of the total heat flux in the fluid layer adjacent to the cooled top plate. The measurements have been undertaken in the large-scale Rayleigh-Bénard experiment "Barrel of Ilmenau" (see left subframe of Figure 1) at Rayleigh numbers up to $Ra = 10^{12}$ and a fixed aspect ratio $\Gamma = 1.1$. An 1d Laser Doppler Anemometer (LDA) and a microthermistor have been used to measure the wall-normal velocity component v_z and the temperature T simultaneously at various distances z from the lower surface of the cooling plate. The measurement volume of the LDA (about 70 µm x 1000µm in size) is aligned besides the thermistor (about 125 µm in diameter) with respect to the orientation of the mean wind. The distance between the centers of the velocity and the temperature sensors is adjusted to be smaller than 300 µm which is about one third of the minimum Kolmogorov length scale in our experiment. The complete set-up is shown in the right sub-frame of Figure 1.

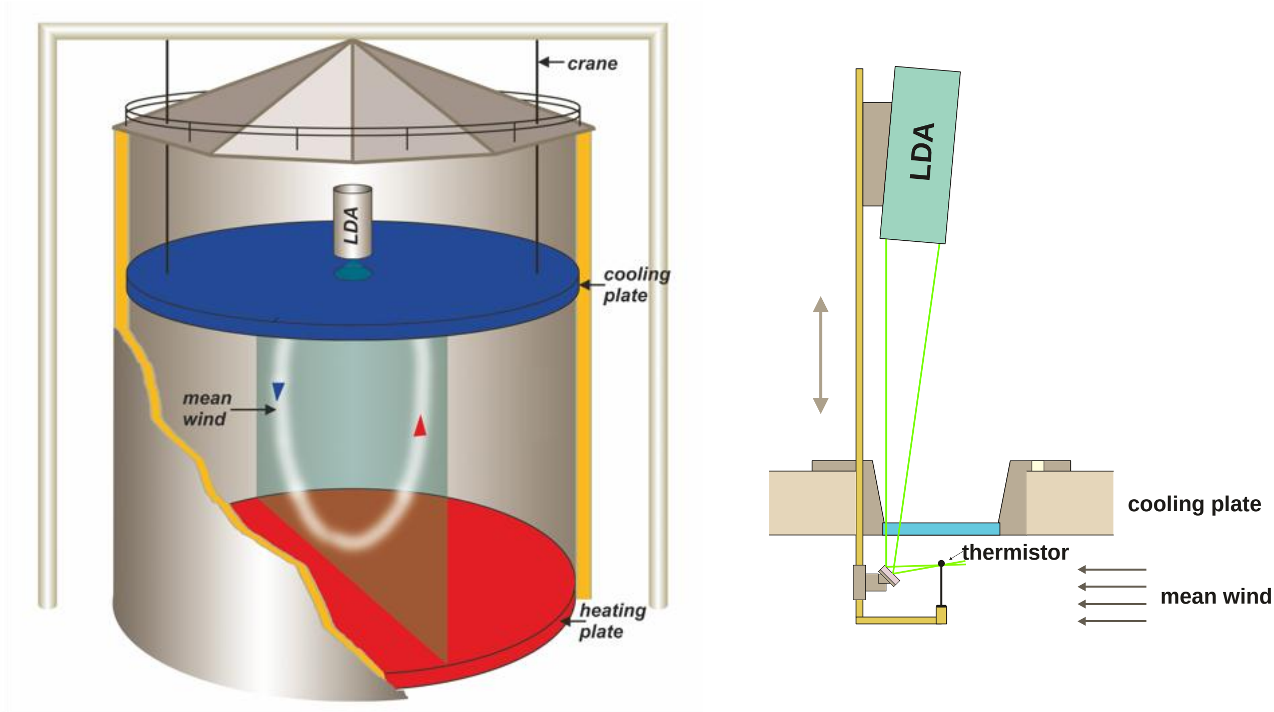

Figure 1. Sketch of the Rayleigh Bénard experiment "Barrel of Ilmenau" (left figure) and set-up of the simultaneous velocity and temperature measurement below the cooling plate (right figure).

Currently, the first measurements are running but the results have yet to be analyzed. In our talk we will present and discuss profiles of both the local diffusive and convective heat flux $\dot{q}_d(z)$ and $\dot{q}_c(z)$, respectively. Particularly, we will focus on the ratio of both fractions and how this ratio depends on the Rayleigh number and the position with respect to the mean wind.

References

[1] Kraichnan, R. H. 1962 Turbulent thermal convection at arbitrary Prandtl number. Phys. Fluids **5**, 1374–1389.