ASPECT RATIO DEPENDENCY OF THE LOCAL HEAT FLUX IN TURBULENT RAYLEIGH-BÉNARD CONVECTION

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In the past century the Rayleigh-Bénard setup became a common model system to investigate natural thermal convection. The flow inside such a Rayleigh-Bénard convection cell is driven by a temperature difference between the top and the bottom plate, while the heat loss throughout the sidewall is suppressed (adiabatic sidewall). A lot of effort has been taken to measure the global heat transport at high Ra (dimensionless temperature difference between top and bottom) spanning a wide Pr range (=kinematic viscosity/thermal diffusivity) an overview is given in [1]. However, it is still unclear how it is locally distributed at the horizontal plates and how this distribution depends on the aspect ratio Γ ($\Gamma = D/H =$ diameter/height).

We report local wall heat flux measurements using heat flux sensors at the surface of the heating plate. The measurements have been carried out in our large-scale Rayleigh-Bénard experiment, called the "Barrel of Ilmenau".The diameter of the cell amounts to $7.15\,\mathrm{m}$ while the distance between the cooling plate and the heating plate can be adjust continuously between $0.15\,\mathrm{m}$ and $6.3\,\mathrm{m}$. The cooling system and the heating system provide a constant temperature boundary conditon whereas Rayleigh numbers up to $Ra = 10^{12}$ depending on the aspect ratio ($1.13 \leq \Gamma \leq 50$) can be achieved, see figure 1 for the full parameter space. The parameter can be extended using a confinement made of acrylic glas which has a diameter of $2.5\,\mathrm{m}$ and variable height aswell the working fluid is air at normal pressure giving $Pr = 0.7$.

Previous investigations in water-filled cylindrical cells have shown a strong variation of the local thickness of the thermal boundary layer at different Rayleigh numbers indicating a non-uniformly distributed heat flux [2]. Own measurements in a small rectangular Rayleigh-Bénard cell of aspect ratio $\Gamma_x = 1$ and $\Gamma_y = 0.26$ at $Ra = 5 \cdot 10^{10}$ shows that the time-average of the local heat flux at the surface of the plates can vary with respect to the position at the plate by about $20\,\%$. The locations of enhanced heat flux could be clearly associated with regions of strong plumeactivity like the area where plumes coming from the opposite plate and hit the plate surface. We assembly 45 thin-film heat flux sensors at the heating plate and measured the local heat flux at 45 positions along the plate surface, while varying the aspect ratio and the Rayleigh number. Since the actual measurements have been started at the beginning of year 2013 the present data, see figure 2, set needs to be extended by further ones to allow well-grounded conclusions.

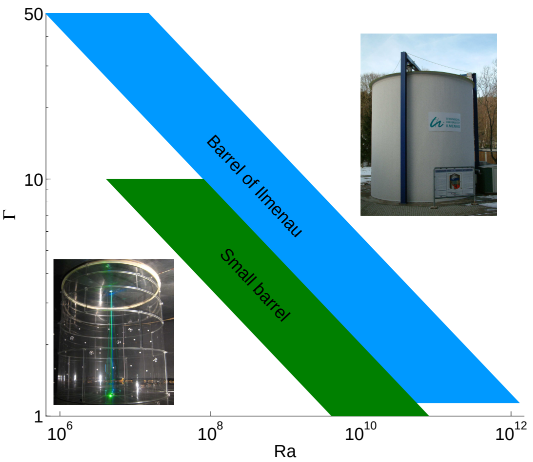

Figure 1. $Ra - \Gamma$-Parameter space of the Barrel of Ilmenau and its inset with a diameter of $2.5\,\mathrm{m}$, called the "Small Barrel"

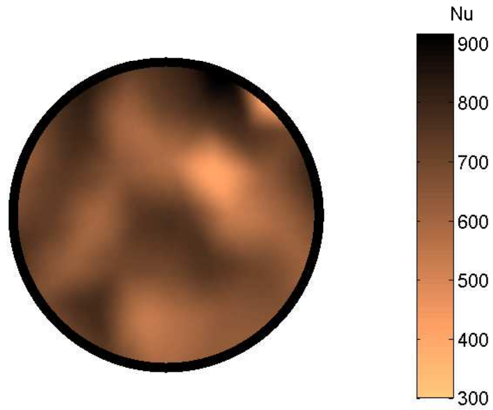

Figure 2. Local Nusselt number measurement at the heating plate of the "Barrel of Ilmenau" at $Ra = 9.4 \cdot 10^{10}$ and $\Gamma = 1.13$

References

[1] G. Ahlers, S. Grossmann, and D. Lohse. Heat transfer and large scale dynamics in turbulent Rayleigh-Benard convection. *Review of Modern Physics*, **81**(2):503–537, 2009.

[2] S.-L. Lui and K.-Q. Xia. Spatial structure of the thermal boundary layer in turbulent convection. *Phyiscal Review E*, **57**(5):5494–5503, 1998.