Turbulent forced convection of air-cooled and air-heated channels

D. Modesti[*], S. Pirozzoli[†]

Heat transfer in cooling ducts is common in many engineering applications and heat exchangers are key components of any energy conversion system. For this reason several textbooks covering this topic are available[1]. However, a common assumption adopted by both numerical and experimental studies is that the temperature behaves as a passive scalar, namely it does not influence the kinematic field. This also implies that density and viscosity variations can be neglected. Even though this is a valid assumption in the case of small temperature variations, it is not representative of engineering configurations where the bulk-to-wall temperature ratio T_b/T_w can be very different from unity. In this study we perform direct numerical simulation of air-cooled and air-heated plane channels with bulk-to-wall temperature ratio $0.5 < T_b/T_w < 3$ for friction Reynolds number in the range $500 < \mathrm{Re}_\tau < 2000$, including the case of symmetric and asymetric heat transfer. Figure 1 shows the temperature field for two representative cases with wall cooling, where it is evident that increasing the bulk temperature increases the global heat flux, but also leads to a lower effective Reynolds number, due to the higher viscosity. In the presentation we will discuss the DNS dataset and the role of density and viscosity variations on the passive scalar assumption.

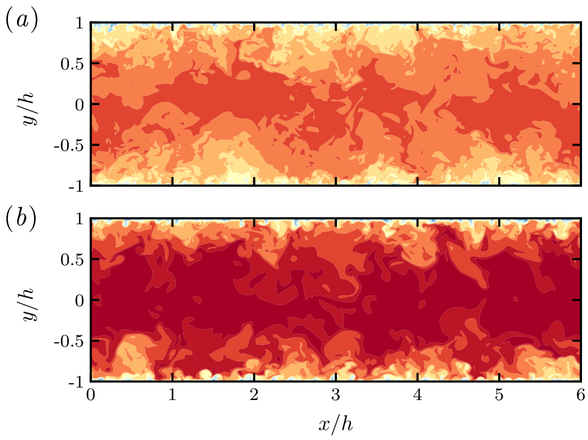

Figure 1: Instantaneous temperature field in inner units for friction Reynolds number $\mathrm{Re}_\tau \approx 1000$ with bulk-to-wall temperature ratio $T_b/T_w = 1.1$ (*a*) and $T_b/T_w = 2$ (*b*). 12 contours are shown in the range $0 < (T - T_w)/T_\tau < 22$, where T_τ is the friction temperature and T_w the wall temperature.

[*]Aeodynamics group, Faculty of Aerospace Engineering, Delft University of Technology
[†]Dipartimento di Ingegneria Meccanica ed Aerospaziala, La Sapienza Università di Roma
[1]W.M. Kays and M.E. Crawford, McGraw-Hill, New York, 1993