Effect of slip boundary conditions on the heat flux and near-wall temperature equations in turbulent Rayleigh-Bénard convection

XIAOZHOU HE, MAOJING HUANG, Harbin Institute of Technology(Shenzhen), YIN WANG, Hong Kong University of Science and Technology, YUN BAO, Sun Yat-Sen University — We present direct numerical simulations (DNS) of the heat transport and near-wall temperature profiles in turbulent Rayleigh-Bénard convection (RBC) with slip boundary conditions (BCs) on horizontal walls. The mean horizontal velocity on the wall is assumed as \( u_w = (b/L)(\partial u/\partial n)|_w \). Here \( L \) is the height of RBC sample, \( b \) is the slip length with \( b = 0 \) for no-slip BC and \( b \to \infty \) for free-slip BC. The simulations were for \( 0 \leq b/L \to \infty \) and the Prandtl numbers \( Pr = 4.3 \) in the Rayleigh-number range \( 10^8 \leq Ra \leq 10^{10} \). As \( b/L \) increases, we found that the ratio of dimensionless heat flux, as expressed by the Nusselt number follows \( Nu/Nu_0 = 0.8 \times \tanh(100 \times b/L) + 1 \), where \( Nu_0 \) is the Nusselt number for \( b = 0 \). Considering the boundary layer fluctuations, we derived the equation \( \Theta(\xi) = \int_0^\xi (1 + p^2 \eta^2)^{-n} \eta \, d\eta \) for the mean temperature profile \( \Theta(\xi) \) near the horizontal surface, where \( p = \Gamma(1 + 1/x)\Gamma(n - 1/x)/\Gamma(n) \) with \( 2 \leq x \leq 3 \) depending on \( b/L \) and \( n > 1 \) for varying geometries of the convection sample.

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