Importance of Achieving Convergence for Computation of Turbulence Through Pipes and Other Ducts

M. Piedrabuena*, S. Hoyas*, E. Sabaresh†, R. Vinuesa† and H. Nagib‡

The most common method to determine the value of the Kármán Coefficient (κ) of a logarithmic part in the mean velocity profiles of wall-bounded turbulence has been the inverse of κ, which is extracted from a constant segment of $\Xi = y^+ \mathrm{d}U^+/\mathrm{d}y^+ = Y\mathrm{d}U^+/\mathrm{d}Y$. Unfortunately, the convergence of direct numerical simulations (DNSs) have not received adequate attention for most of the computations of wall-bounded turbulence. For fully-developed duct flows one approach was advanced several years ago[1] and is adopted here. After many decades of experience with the "canonical" wall-bounded turbulent flows, we recognize that fully-developed pipe as the ideal flow to compare computations and experiments. This understanding was first introduced by the Superpipe Experiments at Princeton and recently advanced by an international effort with an experiment at University of Bologna labeled CICLoPE[2]

We have utilized the "OpenPipeFlow" code of Willis[3] for a large pipe of length $L_z = 10\pi R$. Simulations have been run for $Re_\tau = 180$ and 550 using different meshes in the radial direction r, *i.e.*, containing 384 and 192 points. The meshes used are comparable to or better than many other DNS and run times of up to 200 eddy-turnover times (ETT) that exceeded most of them. Figure 1 displays typical results.

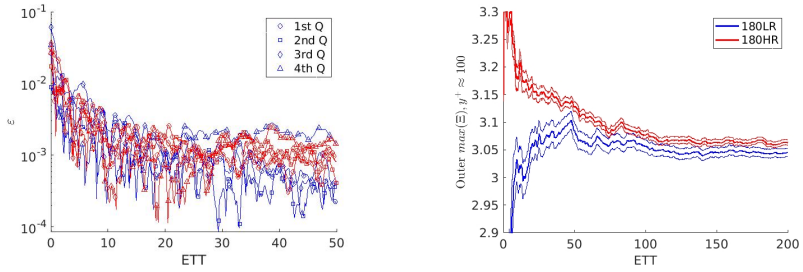

Figure 1: (Left) Time evolution of convergence indicator $\varepsilon_{\mathrm{pipe}}$[1], in four segments of run. (Right) Time evolution of outer maximum and its standard error (95%) of indicator Ξ. Red and blue curves represent finer (HR) and coarser (LR) resolution respectively.

*Instituto Universitario de Matemática Pura y Aplicada, Universitat Politècnica de València, 46022 Valencia, Spain

†FLOW, Engineering Mechanics, KTH Royal Inst. of Tech., SE-100 44 Stockholm, Sweden

‡Armour College of Engineering, Illinois Tech (IIT), Chicago, IL , 60616, USA

[1]Vinuesa R., Prus C., Schlatter P., Nagib H., (2016). "Convergence of numerical simulations of turbulent wall-bounded flows and mean cross-flow structure of rectangular ducts". Meccanica 51:3025–3042.

[2]Nagib, H. M., Monkewitz, P. A., Moscotelli, L., Fiorini, T., Bellani, G., Zheng, X. & Talamelli, A. 2017 Centerline Kármán 'constant' revisited and contrasted to log-layer Kármán constant at CICLoPE. In Proc. TSFP10, Chicago, USA (ed. H. M. Nagib & A. J. Smits).

[3]https://openpipeflow.org/images/d/dc/TheOpenpipeflowSolver.pdf