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The importance of turbulent inflow conditions on unsteady numerical simulations of spatially-developing boundary layers

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Abstract

One of the main challenges on Direct Numerical Simulations (DNS) of turbulent spatially-developing boundary layers is the prescription of proper turbulent conditions at the inlet of the computational domain. In addition, turbulent inflow conditions possess a strong influence on the developing section (a zone where fluctuations behave in a non-physical sense) and downstream evolution of flow and thermal parameters. In this study, the Dynamic Multi-scale Approach (Araya et al. JFM, vol. 670, pp. 581–605, 2011) for prescribing realistic inflow boundary conditions is presented for simulations of spatially developing turbulent boundary layers. The approach is an improved version of the rescaling–recycling method proposed by Lund, Wu & Squires (J. Comput. Phys, vol. 140, pp. 233–258, 1998). The methodology addresses the two limitations of the original rescaling-recycling approach mentioned above: (i) the dependency on empirical correlations for downstream development is solved using a Dynamic approach in which the development of the simulated flow is interrogated to determine the required parameters; and (ii) the limitation of using single velocity scales across different layers is generalized with a Multi-scale procedure that better absorb external conditions. Numerical results of the velocity and thermal fields are shown and discussed for incompressible turbulent flows in spatially-developing boundary layers on zero (ZPG), adverse (APG) and favorable (FPG) pressure gradient flows at low and high Reynolds numbers. Furthermore, applications of the proposed approach are also examined, such as wall roughness modeling, flow separation, relaminarization and stratification.

Biography

Guillermo Araya is a Research Professor in the Department of Mechanical Engineering at Texas Tech University. After completing his Ph.D. degree in Aeronautical Engineering in August 2008 from Rensselaer Polytechnic Institute (Troy, New York, US), he joined the Department of Mechanical Engineering at Johns Hopkins University (Baltimore, Maryland, US) as a Postdoctoral Fellow under the supervision of Prof. Charles Meneveau. He has been a Research Assistant at Swansea University (UK) from 2009 to 2011. His research interests include computational fluid dynamics of turbulent incompressible and compressible flows, wind energy array modeling, DNS, LES, RANS, URANS, turbulence modeling, heat transfer and flow control.