DNS and Visual Analysis of Superstructures in Turbulent Channels with Mixing by Parallel Injection

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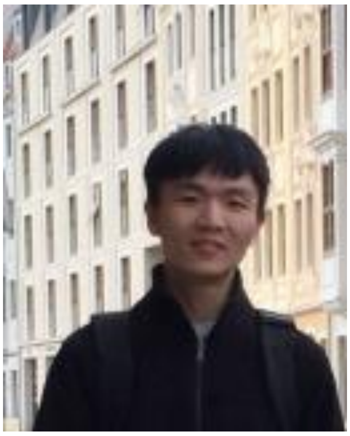

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Abstract: In order to analyze the occurrence and the impact of superstructures on turbulent mixing in channels at high Reynolds numbers with a parallel injection, a combination of Direct Numerical Simulation (DNS), vortex definition and identification, and feature-based visualization, is proposed. Concerning DNS, the central issue is to access high Reynolds numbers with excellent efficiency on HPC systems. Additionally, suitable models must be included to describe numerically all fluid properties relevant for mixing. The main challenge in vortex extraction is three-fold. Firstly, high-intensity turbulence excludes standard vortex definitions that are based on a local analysis of the flow derivatives. Instead, global, Lagrangian, or hierarchical vortex definitions are necessary that are based on filtering operations on the flow map instead of the velocity field. Secondly, vortex definitions and parameter tuning has to be adapted such that it does not focus on upstream vortices close to injection but tackles the less obvious, noisier and more unsteady vortex structures downstream. Thirdly, in terms of visual analysis, the main challenge is associated with the sheer size of the data sets: DNS typically delivers data sets that cannot be completely stored during the simulation. Hence, on-the-fly solutions for the visual analysis are necessary. To analyze the phenomena, DNS, vortex extraction and visualization have to be combined into a feedback cycle in a computational steering sense. While a multi-scale POD along with an automatic vortex extraction is carried out on-the-fly, the resulting vortices are later

visually analyzed in an interactive manner, allowing adaptation of both the visualization parameters and further simulation parameters. This efficient combination of DNS, POD, and visual analysis shall allow the identification of superstructures and help explain their impact on transport processes.