Analyzes and comparisons between large-eddy simulation and direct numerical simulation of a turbulent channel flow

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Objectives

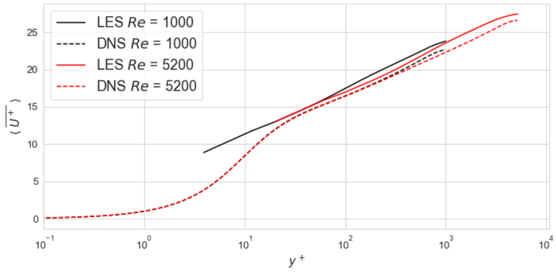
The objective of this work is to analyze the performance of a medium cost model in turbulence analyzes, the Large-Eddy Simulation (LES), comparing its efficiency with the ideal and more computationally expensive model, the Direct Numerical Simulation (DNS), when both simulate equal Reynolds (Re) numbers (1000 and 5200) in a channel flow. By definition, LES does not resolve small fluctuations in turbulent flow, it only models them. In this sense, emphasis is placed on the part adjacent to the channel surface, where the differences between the two models tend to be greater since in this region the small fluctuations play an important role and the LES only implements a boundary condition to account for its influence on the layers above.

Materials and Methods

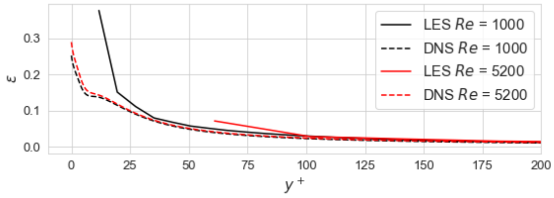
As the parameters of interest for a turbulent flow are mostly statistical, Python programming language was widely used to model and calculate these parameters from the data extracted from the simulations, both for LES and DNS, the first ran by the research group, and the second extracted from [1]. Most of the calculations performed are under the theories developed in [2].

Results

The results showed an excellent agreement between the LES and DSN for both simulated Reynolds, mainly away from the wall, as shown in Figure 1. There is a certain discrepancy in the values related to the smaller scales, which get relevant as they approach the wall, such as covariance and, consequently, energy dissipation terms, as shown in Figure 2.



Picture 1: Mean streamwise velocity



Picture 2: Dissipation profile

Conclusions

In general, the LES fulfills its role of solving the largest scales reliably and modeling the smallest scales within acceptable errors. However, the fact that the code does not resolve the wall-adjacent layer is an important limitation that should motivate the implementation of alternative boundary conditions that produce better results in that part of the channel.

References

[1] Lee, M., & Moser, R. D. (2015). Direct numerical simulation of turbulent channel flow up to Reτ ≈ 5200. *Journal of Fluid Mechanics*, *774*(2015), 395–415. https://doi.org/10.1017/jfm.2015.268

[2] Pope, S. (2000). Turbulent Flows. Cambridge University Press.