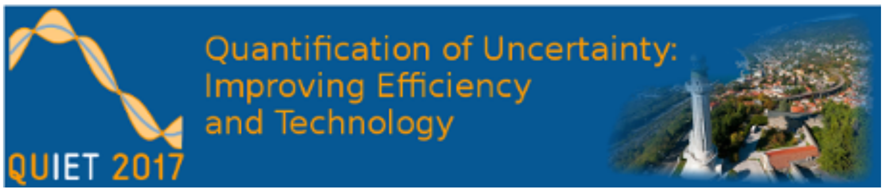

Stochastic sensitivity analysis to grid resolution and closure modeling in large-eddy simulation

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Nowadays, large-eddy simulation (LES) is increasingly applied to complex flow configurations of interest in technological or environmental applications. In this context, the assessment of the quality and reliability of LES results has become a topic of increasing interest. A systematic exploration of the sensitivity to the different parameters involved in the computational set up or in physical modeling is difficult for LES, due to the large costs of each single simulation, and it may become unaffordable for complex cases or when a large number of parameters is involved. A possible approach, which is being increasingly used in recent years in computational fluid dynamics, is Uncertainty Quantification (UQ), in which the uncertain or unknown parameters are modeled as input random variables with a given probability distribution. These uncertainties can be propagated through the computational model to statistically quantify their effect on the results. Since this propagation process implies large computational costs, especially for LES, a computationally inexpensive surrogate model is usually adopted to build continuous response surfaces in the parameter space.

As an example of stochastic sensitivity analysis to discretization and modeling parameters, we consider herein the flow around a 5:1 rectangular cylinder, which is the object of an international benchmark (BARC) collecting experimental and numerical flow realizations [1]. The BARC configuration is of practical interest, e.g. in civil engineering, and, in spite of the simple geometry, the related flow dynamics and topology is complex. Significant dispersion of the BARC predictions was observed for some quantities, also in LES, and deterministic sensitivity analyses were not conclusive. LES are carried out here by using a spectral-element numerical method. An explicit quadratic low-pass filter in the modal space is used, characterized by a cut-off value and by a weight function, which provides dissipation of the modes higher than the cut off and acts as a SGS dissipation. The uncertain parameters are the size of the spectral elements in the spanwise direction and the weight of the explicit filter. The latter has been chosen because it directly controls the amount of SGS dissipation, while the sensitivity to the grid resolution in the spanwise direction is investigated because of the high impact of this parameter shown in some of the LES simulations (see the discussion in [1]). The impact of the uncertainty in these parameters is evaluated through generalized polynomial chaos. The most-probable values and the stochastic variance of the results are compared with the ensemble average and with the overall dispersion of the BARC predictions respectively.

References

[1] L. Bruno, M. V. Salvetti, and F. Ricciardelli. Benchmark on the Aerodynamics of a Rectangular 5:1 Cylinder: an overview after the first four years of activity. *J. Wind Eng. Ind. Aerod.*, 126:87–106, 2014.