Examples of Application of Uncertainty Quantification Techniques in Study of Wall-Bounded Turbulent Flows

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Uncertainty Quantification (UQ) is one of the most recent and fast-evolving branches of mathematics and computational sciences which potentially improves our understanding of the models involved in simulation of physical phenomena.

The aim of the present study is first to shortly review some sources of uncertainty involved in Large Eddy Simulation (LES) of wall-bounded turbulent flows in general and then to show how the inverse and forward problems within UQ framework can be formulated to study the Near-Wall Modeled LES (NWM-LES) approach in particular. The key feature of this approach is proper estimation of wall shear stress that can be done using a wall function. Contrary to general belief the model parameters of such a function appear not to be universal and are hence needed to be adjusted by applying Bayesian techniques to the available numerical and experimental benchmark data. The uncertainties involved in these parameters propagate into the solution and affect the quantities of interest and model responses. This issue is addressed via forward and sensitivity analysis of a model ordinary differential equation (ODE) which calculates the mean velocity profile of turbulent channel flow.

Another important issue that is discussed is accounting for the uncertainties involved in the experimental data employed to estimate the parameters of the wall functions. The details of a collaborative study performed to evaluate sensitivity of velocity and wall shear stress respectively measured by hot-wire anemometry and oil-film interferometry techniques to several sources of uncertainty are presented. In a wider view, these uncertainties propagate into the wall function and then find their ways into the predictions of NWM-LES. Understanding and proper accounting for all these errors help us take one step forward toward reliable predictive numerical simulation of wall-bounded turbulent flows.