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An adjoint-based Bayesian approach for data assimilation and uncertainty quantification in Reynolds-Averaged Navier-Stokes modeling

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Abstract

Turbulence modeling is an essential tool to obtain affordable predictions of complex flows. In particular, Reynolds-Averaged Navier-Stokes (RANS) modeling may be considered to obtain mean-flow predictions at low computational cost. However, deficiencies in turbulence modeling may alter the fidelity of RANS predictions, motivating the consideration of data-assimilation techniques to enhance such predictions based on reference data. In this presentation, we discuss an adjoint-based Bayesian approach that not only provides improved mean-flow predictions from limited data, but also quantifies the associated uncertainties. The present approach is designed to rigorously deal with non-parametric modeling deficiencies, namely to infer spatially-dependent corrective terms, and relies on a high-order adjoint technique to accurately predict posterior statistics at an affordable computational cost. The potentialities of this approach are illustrated considering two turbulent flows: the flow in a converging-diverging channel and the one past a near-stall airfoil. In both cases, it is shown that, relying on a limited number of pointwise data, significant improvements in the RANS-based mean-flow predictions are obtained along with correct estimations of the remaining reconstruction errors.

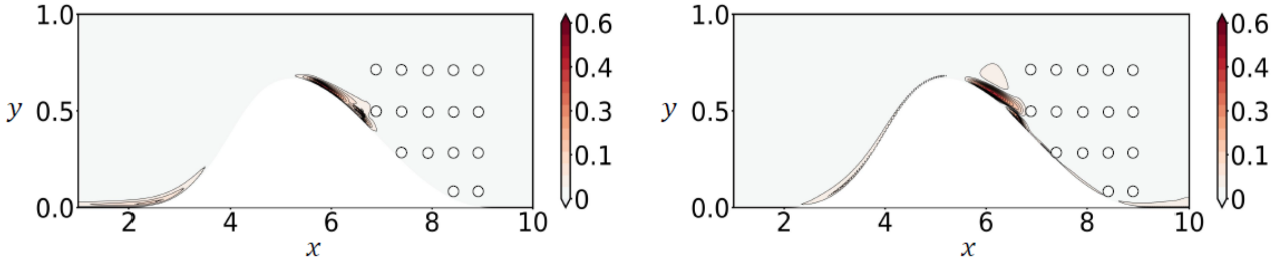

Figure 1: Left: predicted standard deviation in the reconstructed mean streamwise velocity based on pointwise velocity data at the locations marked by white dots; right: actual remaining reconstruction errors with respect to full DNS data.

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