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Quantifying Model-Form Uncertainties in Reynolds Averaged Navier-Stokes Equations: An Open-Box, Physics-Based, Bayesian Approach HENG XIAO, JINLONG WU, JIANXUN WANG, RUI SUN, CHRISTOPHER J. ROY, Virginia Tech — For many practical flows, the turbulence models are the most important source of uncertainty in Reynolds-Averaged Navier-Stokes (RANS) predictions. In this work, we develop an open-box, physics-informed Bayesian framework for quantifying the model-form uncertainties in RANS simulations. Uncertainties are introduced directly to the Reynolds stresses and are represented with compact parameterization accounting for empirical prior knowledge and physical constraints (e.g., realizability, smoothness, and symmetry). An iterative ensemble Kalman method is used to incorporate the prior information with available observation data in a Bayesian framework to posterior distributions of the Reynolds stresses and other quantities of interest. Two representative cases, the flow over periodic hills and the flow in a square duct, are used to evaluate the performance of the proposed framework. Simulation results suggest that the obtained posterior mean has significantly better agreement with the benchmark data compared to the baseline simulation, even with very sparse observations. At most locations, the posterior distribution adequately represents the model-form uncertainties.

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