Chowdhary, Kenny; Hoang, Chi; Lee, Kookjin; Ray, Jaideep; Weirs, V. G.; Carnes, Brian
Calibrating hypersonic turbulence flow models with the HIFiRE-1 experiment using data-driven machine-learned models. (English) Zbl 07614971

Summary: In this paper we study the efficacy of combining machine-learning methods with projection-based model reduction techniques for creating data-driven surrogate models of computationally expensive, high-fidelity physics models. Such surrogate models are essential for many-query applications e.g., engineering design optimization and parameter estimation, where it is necessary to invoke the high-fidelity model sequentially, many times. Surrogate models are usually constructed for individual scalar quantities. However there are scenarios where a spatially varying field needs to be modeled as a function of the model’s input parameters. We develop a method to do so, using projections to represent spatial variability while a machine-learned model captures the dependence of the model’s response on the inputs. The method is demonstrated on modeling the heat flux and pressure on the surface of the HIFiRE-1 geometry in a Mach 7.16 turbulent flow. The surrogate model is then used to perform Bayesian estimation of freestream conditions and parameters of the SST (Shear Stress Transport) turbulence model embedded in the high-fidelity (Reynolds-Averaged Navier-Stokes) flow simulator, using shock-tunnel data. The paper provides the first-ever Bayesian calibration of a turbulence model for complex hypersonic turbulent flows. We find that the primary issues in estimating the SST model parameters are the limited information content of the heat flux and pressure measurements and the large model-form error encountered in a certain part of the flow.

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76-XX Fluid mechanics
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reduced order modeling; machine learning; Bayesian; MCMC; neural networks; uncertainty quantification

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