Multi-Fidelity Monte Carlo Methods for Gas Dispersion Problems under Uncertain Inflow Conditions

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In this work, the dispersion of airborne contaminant is described by employing steady-state incompressible Navier–Stokes (INS) equations and a subsequent advection-diffusion (AD) problem. Varying surrounding wind conditions are additionally incorporated by a parametric Dirichlet boundary condition applied to the INS problem. To enable near real-time evaluations and computationally feasible multi-query analyses, previous works focused on deriving reduced-order model (ROM) approximations for the INS problem as the computational bottleneck in [1] and the coupled problem in [2]. These ROMs can replace the full-order model (FOM) in, for instance, Monte Carlo simulations. However, errors introduced by the ROM in approximating the wind field can lead to increased errors in the spatio-temporal concentration field, which accumulate over time. Therefore, Multi-Fidelity Monte Carlo [2] approaches are discussed to enhance the accuracy in Monte Carlo estimations while preserving computational efficiency. They rely on the developed ROM as low-fidelity model and the FOM as high-fidelity model. Furthermore, the relationship between the models is learned using Gaussian processes. By incorporating this relationship, Monte Carlo estimates are obtained, that closely approximate the high-fidelity results, with evaluations predominantly performed on the computationally efficient ROM. Thus, run times can be drastically reduced with only minor accuracy losses. This facilitates assessments of the influence of uncertain surrounding wind conditions and ”what-if” studies for the presented application.

References:

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