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CLOSURE MODELING FOR THE PROPER ORTHOGONAL DECOMPOSITION OF TURBULENT FLOWS: MODELS AND ANALYSIS

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The reduced order models (ROMs) are frequently used in the simulation of complex flows to overcome the high computational cost of direct numerical simulations, especially for three-dimensional nonlinear problems. The proper orthogonal decomposition (POD), as one of the most commonly used tools to generate ROMs, has been utilized in many engineering and scientific applications. Its original promise of computationally efficient, yet accurate approximation of coherent structures in high Reynolds number turbulent flows, however, still remains to be fulfilled. To balance the low computational cost required by ROMs and the complexity of the targeted flows, appropriate closure modeling strategies need to be employed.

In this talk, we put forth several closure models for the POD-ROMs of structurally dominated turbulent flows [1]. These models, which are considered state-of-the-art in large eddy simulation, are carefully derived and numerically investigated. We also discuss several approaches for an efficient and accurate numerical discretization of general nonlinear POD closure models [2]. We numerically illustrate these developments in several computational settings, including a three-dimensional turbulent flow past a cylinder at Reynolds number $Re = 1000$. A rigorous numerical analysis of the new computational framework will also be presented. A special emphasis will be placed on the effect of the snapshot difference quotients on the optimality of the error estimates with respect to the number of POD modes retained in the ROM.

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