Aerospace Engineering Doctoral Defense

Accuracy and Computational Stability of Tensorally-Correct Subgrid Stress and Scalar Flux Representations in Autonomic Closure of LES

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Abstract

Autonomic closure is a recently-proposed subgrid closure methodology for large eddy simulation (LES) that replaces the prescribed subgrid models used in traditional LES closure with highly generalized representations of subgrid terms and solution of a local system identification problem that allows the simulation itself to determine the local relation between each subgrid term and the resolved variables at every point and time. The present study demonstrates, for the first time, practical LES based on fully dynamic implementation of autonomic closure for the subgrid stress and the subgrid scalar flux. It leverages the inherent computational efficiency of tensorally-correct generalized representations in terms of parametric quantities, and uses the fundamental representation theory of Smith (1971) to develop complete and minimal tensorallycorrect representations for the subgrid stress and scalar flux. It then assesses the accuracy of these representations via a priori tests, and compares with the corresponding accuracy from nonparametric representations and from traditional prescribed subgrid models. It then assesses the computational stability of autonomic closure with these tensorally-correct parametric representations, via forward simulations with a high-order pseudo-spectral code, including the extent to which any added stabilization is needed to ensure computational stability, and compares with the added stabilization needed in traditional closure with prescribed subgrid models. Further, it conducts a posteriori tests based on forward simulations of turbulent conserved scalar mixing with the same pseudo-spectral code, in which velocity and scalar statistics from autonomic closure with these representations are compared with corresponding statistics from traditional closure using prescribed models, and with corresponding statistics of filtered fields from direct numerical simulation (DNS). These comparisons show substantially greater accuracy from autonomic closure than from traditional closure. This study demonstrates that fully dynamic autonomic closure is a practical approach for LES that requires accuracy even at the smallest resolved scales.

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Zoom Link: https://asu.zoom.us/j/83279969669