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A dynamic recursive neural-network-based subgrid-scale model for large eddy simulation

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Abstract

We develop a subgrid-scale (SGS) model for large eddy simulation (LES) using an artificial neural network (NN) trained from resolved flow variables. Since NNs are weak at extrapolation, it is a challenging work to develop an NN-based SGS model that can be applied to untrained flow geometries, untrained Reynolds numbers, and different grid sizes. Cho, Park and Choi (2024, JFM) proposed a new recursive NN-based SGS model trained from 3D forced homogeneous isotropic turbulence (HIT) at low to high Reynolds numbers, and showed an excellent prediction capability for both forced and decaying HITs at untrained Reynolds numbers. Because this recursive approach was applied to only HITs, it may not be applicable to the predictions of very different flows such as turbulent channel flow or flow over a circular cylinder. Therefore, in the present study, we introduce a coefficient in front of the NN, $\tau_{ij} = c_d$ NN(input variable), and obtain c_d dynamically (similar to that of dynamic Smagorinsky model (Germano et al. 1990, PoF)). The input variable is similar to the classical SGS model of Vreman (2004). We apply this dynamic recursive NN-based SGS model (trained only from HIT) to turbulent channel flow and flow over a circular cylinder, and show that the results are similar to or even better than those by traditional SGS models.

Keywords: Large eddy simulation, Subgrid-scale model, Artificial neural network, Dynamic recursive NN