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# The Direct Deconvolution Model for the Large Eddy Simulation of Turbulence

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**Abstract :** Large eddy simulation (LES) has been extensively used in the investigation of turbulence. LES calculates the grid-resolved large-scale motions and leaves small scales modeled by sublfilterscale (SFS) models. Among the existing SFS models, the deconvolution model has been used successfully in the LES of the engineering flows and geophysical flows. Despite the wide application of deconvolution models, the effects of subfilter scale dynamics and filter anisotropy on the accuracy of SFS modeling have not been investigated in depth. The results of LES are highly sensitive to the selection of filters and the anisotropy of the grid, which has been overlooked in previous research. In the current study, two critical aspects of LES are investigated. Firstly, we analyze the influence of sub-filter scale (SFS) dynamics on the accuracy of direct deconvolution models (DDM) at varying filter-to-grid ratios (FGR) in isotropic turbulence. An array of invertible filters are employed, encompassing Gaussian, Helmholtz I and II, Butterworth, Chebyshev I and II, Cauchy, Pao, and rapidly decaying filters. The significance of FGR becomes evident, as it acts as a pivotal factor in error control for precise SFS stress prediction. When FGR is set to 1, the DDM models cannot accurately reconstruct the SFS stress due to the insufficient resolution of SFS dynamics. Notably, prediction capabilities are enhanced at an FGR of 2, resulting in accurate SFS stress reconstruction, except for cases involving Helmholtz I and II filters. A remarkable precision close to 100% is achieved at an FGR of 4 for all DDM models. Additionally, the further exploration extends to the filter anisotropy to address its impact on the SFS dynamics and LES accuracy. By employing dynamic Smagorinsky model (DSM), dynamic mixed model (DMM), and direct deconvolution model (DDM) with the anisotropic filter, aspect ratios (AR) ranging from 1 to 16 in LES filters are evaluated. The findings highlight the DDM's proficiency in accurately predicting SFS stresses under highly anisotropic filtering conditions. High correlation coefficients exceeding 90% are observed in the a priori study for the DDM's reconstructed SFS stresses, surpassing those of the DSM and DMM models. However, these correlations tend to decrease as lter anisotropy increases. In the a posteriori studies, the DDM model consistently outperforms the DSM and DMM models across various turbulence statistics, encompassing velocity spectra, probability density functions related to vorticity, SFS energy flux, velocity increments, strain-rate tensors, and SFS stress. It is observed that as filter anisotropy intensify, the results of DSM and DMM become worse, while the DDM continues to deliver satisfactory results across all filter-anisotropy scenarios. The findings emphasize the DDM framework's potential as a valuable tool for advancing the development of sophisticated SFS models for LES of turbulence.

**Keywords :** deconvolution model, large eddy simulation, subfilter scale modeling, turbulence
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