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Fractional gradient based subgrid-scale models of turbulence[1]

PATRICIO CLARK DI LEONI, TAMER ZAKI, Johns Hopkins University, GEORGE KARNIADAKIS, Brown University, CHARLES MENEVEAU, Johns Hopkins University — In large eddy simulations, the effects of the unresolved scales are encapsulated in the turbulence subgrid-scale model. Whether the model can reproduce the correct two-point correlations in the filtered velocity field in LES is governed by its Karman-Howarth equation, and specifically whether the model correctly captures the two-point correlation functions between the stresses and the filtered strain-rates. Inspired by this statistical necessary condition, we develop a model that takes into account non-local effects by using fractional derivatives, and evaluate its performance using data from the Johns Hopkins Database (JHTDB). Starting from direct numerical simulation data of homogeneous isotropic turbulence and channel flows, we filter the data to separate the small and large scales, and calculate the two-point stress-strain rate correlations for the exact case and for models (a-priori) with different fractional orders. We observe that the Smagorinsky model based on standard gradients fails to produce the long range correlations observed in the exact case, while the fractional-gradient models capture the longer tails of the true correlations. As one approaches the wall in channel flow, more complex, highly anisotropic behavior is found.

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