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A-PRIORI ANALYSIS OF STATIC AND DYNAMIC SUB-GRID SCALE CLOSURES CONDITIONAL ON THE COHERENT STRUCTURE OF THE FLOW

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For the purpose of a-priori analysis, a direct numerical simulation database resembling homogeneous isotropic turbulence, uniformly discretized by 512^3 grid points, has been explicitly filtered using a Gaussian filter kernel for varying filter width. It is particularly instructive to analyze the sub-grid scale model performance conditional on the value of the coherent structure function, i.e. the normalized second invariant of the velocity gradient tensor. In this way, not only the average of the kinetic energy dissipation but also its distribution with respect to strain- and rotation-dominated flow regions can be assessed. Compared to usual performance measures, this clearly reveals the deficiencies of some models available in the literature. In the context of this work, it is important to mention that the calculation of derivatives (second-order central differencing) and explicit test filtering are based on the grid corresponding to the large eddy simulation.
Well-known functional models (e.g. Smagorinsky, Nicoud, Kobayashi) as well as structural models (e.g. Clark, Bardina/Liu, generic non-linear model) are examined by means of correlation coefficients and field norms. Additionally, different formulations of the dynamic procedure based on the scale similarity principle (as originally proposed by Germano, and later improved by Lilly) are investigated. A particular focus is placed on the influence of the filter width of the explicit test filter and how this affects the results of (dynamic) scale similarity type models. It is also demonstrated that the vector level correlation, i.e. after taking the divergence of the model tensor, decreases considerably from strain- to rotation-dominated flow, even when the tensor level correlation, i.e. before taking the divergence, is approximately independent of the coherent structure function.
The results indicate that a properly formulated sub-grid scale model should be able to reproduce the different behavior depending on the local flow structure, which is consistent with the intricate dissipation-enstrophy interplay in turbulent flows.

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