

Subgrid modelling for LBM-based Large-eddy simulation

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Résumé :

Cette contribution traite de la fermeture sous maille pour les modèles numériques basés sur la méthode de Boltzmann sur réseau (Lattice Boltzmann Method – LBM). Outre l'adaptation du modèle de Smagorinsky consistant en Reynolds, une approche originale, qui fait appel à la structure de l'équation de départ suivant une démarche de type déconvolution approchée est proposée. Cette dernière approche conduit à une fermeture qui ne repose pas sur le concept de viscosité turbulente.

Abstract :

This paper deals with new subgrid models for Lattice-Boltzmann-based simulations of turbulent flows. A first part will be devoted to the extension of Inertial-Range Consistent Smagorinsky models. In a second part, an original approach based on Adams' Approximate Deconvolution Procedure is presented. This new LES-LBM method doesn't rely on the eddy-viscosity assumption, and takes into account the fact that LBM equations exhibit an exponential nonlinearity instead of the quadratic one found in Navier-Stokes equations.

Mots clefs: turbulence, large-eddy simulation, lattice Boltzmann method

Direct simulation of hydrodynamic turbulence is beyond the reach of available computational facilities in most practical cases, because of the huge amount of degrees of freedom required to capture all scales of a turbulent flow. Large-eddy simulation (LES) is a computational approach that aims at alleviating this problem by removing the smallest scales of the turbulent motion. According to Kolmogorov's celebrated local isotropy hypothesis, these small scales are expected to exhibit a higher degree of universality than the larger ones, and their modelling is therefore assumed to be easier. Finding this model for unresolved scales, which is referred to as a subgrid model, has motivated a huge amount of works during the past decades in the classical Navier-Stokes framework. But only a very few works have addressed this issue in the LBM context. Some recent advances will be presented, along with some possible open research perspectives.

Recent advances in the field of LES have also emphasized the subtle coupling which exists between the numerical method and the subgrid model in Navier-Stokes-based methods. This point remains almost not addressed up to now for LBM-based LES. Recent results dealing with the prediction of 2-point correlations of turbulent fluctuations will be presented.

At last, the more fundamental issue of writing the relevant governing equations for LBM-LES will be considered, since the nonlinearity doesn't have the same form in the Navier-Stokes and the LBM case. To this end, an original method based on Adams' Approximate Deconvolution Method is proposed. This new method doesn't rely on any assumption on subgrid scale dynamics, and fully account for the mathematical structure of LBM governing equations. An important difference with Navier-Stokes equations stems from the non-linearity : while a quadratic nonlinearity is present in Navier-Stokes equations, an exponential one appears in LBM equations. Therefore, adapted subgrid closures can be found, which may differ from the usual subgrid models, and which are closer to the initial structure of the governing model than the usual extension of Smagorinsky's subgrid-viscosity. Several versions of the LBM closure will be presented.

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