Subgrid-scale model tests using petascale computers

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Large-eddy simulation (LES) has become an effective research tool for the atmospheric bound¬ary layer (ABL) and probably the most in the atmospheric surface layer LES suffers from inherent under-resolution and poor subgrid-scale (SGS) model performance. To develop improved SGS models a methodology for testing model perfor¬mance is needed. Previous tests rely on comparing the modeled and measured/DNS SGS stress (apriori tests) or comparing LES and measured profiles (a posteriori tests). Such test methods have severe limitations. From apriori tests it is difficult to predict the effects of model behavior on LES results, e.g., the correlation between the modeled and measured SGS stress components provides little information about model performance in simulations. From a posteriori tests it is difficult to relate deficiencies of LES results (e.g., the mean velocity and Reynolds stress profiles) to specific aspects of the model behavior. The two types of tests are disconnected as they deal with different variables (instantaneous SGS stress and LES statistics), respectively. Therefore, apriori and a posteriori test results cannot be directly compared to further evaluate model performance.

To overcome these limitations, we have developed a systematic test approach based on the necessary conditions for LES to predict correctly the joint probability density function of the resolvable-scale velocity and scalar. The JPDF contains all single-point velocity-scalar statistics, thereby making it possible to relate model test results to LES statistics, i.e., to model performance in simulations. The test method can be employed to study SGS model performance in simulations using LES fields. The test method relies on conditional statistics, therefore require large data sizes for sufficient statistical convergence. As a result, current tests are limited to using a subset of the velocity components as conditioning variables. Petascale computing facilities can accommodate larger computational domains, higher spatial resolutions, and longer runs, which will result in larger amounts of independent samples, thereby allowing tests that are not feasible with today's computers. Therefore, petascale computing facilities present a unique opportunity to improve LES of the ABL.