Physical consistency of subgrid-scale models for large-eddy simulation

Maurits Silvis*, Ronald Remmerswaal and Roel Verstappen
Johann Bernoulli Institute for Mathematics and Computer Science, University of Groningen, Nijenborgh 9, 9747 AG Groningen, The Netherlands

February 14, 2017

Abstract The behavior of many practical turbulent flows cannot be predicted directly by the Navier-Stokes equations, because not enough computational resolution is available to resolve all relevant scales of motion. We therefore turn to large-eddy simulation (LES). In large-eddy simulation, the large scales of motion in a flow are explicitly solved for, whereas small-scale motions are modeled. The question is, however, how to model these small-scale (or subgrid-scale) motions and their effect on the large-scale features of turbulent flows? We present a systematic approach of constructing subgrid-scale (or turbulence) models that is based on the idea that it is desirable that subgrid-scale models are consistent with the mathematical and physical properties of the Navier-Stokes equations and the turbulent stresses. We will discuss several such properties, including the symmetries of the Navier-Stokes equations, and the near-wall scaling behavior, realizability and dissipation properties of the turbulent stresses. As such, a framework of model constraints arises that we apply to analyze the behavior of existing subgrid-scale models. We furthermore show how this framework can be used to construct new subgrid-scale models with desirable properties built into them. An example of a new model of eddy viscosity type is presented, which was succesfully tested in large-eddy simulations of homogeneous isotropic turbulence and plane-channel flow.

References

[1] Silvis, M. H., Remmerswaal, R. A., and Verstappen, R. “Physical consistency of subgrid-scale models for large-eddy simulation of incompressible turbulent flows”. In: *Phys. Fluids* 29, 015105 (2017). DOI: 10.1063/1.4974093.

*Email address: m.h.silvis@rug.nl