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Speaker: Dr. Ugo Piomelli
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Title: "On the use of hybrid RANS/LES methods for wall-layer modeling"

Abstract

Large-eddy simulations (LES) have become increasingly popular as a tool to compute turbulent flows with more accuracy and at higher levels of detail than can be achieved by turbulence models for the Reynolds-Averaged Navier-Stokes (RANS) equations, at a fraction of the cost of Direct Numerical Simulations (DNS). LES have been applied successfully to a considerable variety of flows of engineering and geophysical interest, and have contributed to significant improvements in the understanding of the physics of turbulent flows.

One area in which the cost advantages of LES over DNS are less clear is in the calculation of wall-bounded flows: the grid requirements of DNS and LES in this case are comparable, due to the need to resolve the momentum-producing eddies, whose size depends on the Reynolds number. For high-Reynolds-number flows, one must instead bypass the wall-layer and determine the wall stress as a function of the velocity in the outer layer, an approach analogous to the wall functions commonly used in RANS methods. Various approaches exist; recently, the hybridization of LES with RANS for the simulation of high-Reynolds number wall-bounded flows is receiving intense attention.

The quasi-steady RANS equations are solved in the near-wall region with shallow grid cells, while an LES is performed away from the wall with nearly cubic cells. This technique, however, creates a transition layer between the RANS and LES regions, in which the shear stress is fully modeled and fully resolved, respectively. This may result in inaccurate velocity profiles, Typically involving an upward shift in the LES logarithmic region, and errors of up to 15% in skin friction. The present study compares methods to couple the inner, RANS, region to the outer, LES, one; in particular, the location of the interface between the two regions, and the type of model used in each are examined. Calculations of turbulent channel flow show that accurate predictions of length- and time-scales of the turbulent eddies in the RANS region are important, but are not the only factors determining accuracy. Modeling errors in the LES region also influence the mean flow profiles. Recent investigations have focused on the addition of stochastic forcing to the momentum equations, an effect that can eliminate the error in the skin friction prediction.