

Chapter 12

VLES of flows driven by thermal buoyancy and magnetic field

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Abstract The unsteady Reynolds-averaged-Navier-Stokes (T-RANS) approach is proposed as a convenient tool for predicting turbulent flows dominated by large-scale deterministic eddy structure. This method can be regarded as Very Large Eddy Simulation (VLES) in which the large scale deterministic motion is fully resolved, whereas the unresolved random motion is modeled by a "subscale" model for which an one-point RANS closure is used. The resolved and modeled contribution to the turbulence moments are of the same order of magnitude and in near-wall regions the modeled part becomes dominant, emphasizing the role of the subscale model, particularly in predicting wall phenomena. This approach, with an algebraic stress/flux subscale model, was verified earlier in comparison with direct numerical simulation and experiments in classic Rayleigh-Bénard convection over flat and wavy walls in a range of Rayleigh numbers. It is applied here to simulate the magnetic Rayleigh-Bénard convection in both a moderate and in a strong uniform magnetic field oriented in the vertical direction. The simulations enables to capture effect of the magnetic field on the mean flow, wall heat transfer, as well as on reorganization of the large-scale coherent eddy structure.

12.1 Introduction

Large Eddy Simulation (LES) is nowadays viewed as a mature technique for studying certain types of turbulent flows. Its potential is especially useful for simulating separating and other flows with dominant large eddy structures, though only at low to moderate Reynolds and Rayleigh numbers. The major limitation, however, is in the excessive computational costs which increase sharply with the Reynolds and Rayleigh numbers, associated with the need to resolve a larger and larger range of eddy scales. Complex geometries are still difficult to handle, and the treatment of wall boundaries is a serious challenge that has not yet been fully resolved. The resolution of near-wall flow regions is especially problematic if wall friction and heat transfer are in focus. A proper resolving of the buffer region and capturing the streaky structures and small-scale eddies occupying this region requires a sufficiently fine computational mesh not only in the wall-normal direction, but also in the spanwise and streamwise directions. The required mesh density becomes comparable with that for a complete direct numerical simula-