# Investigation on wall-resolved and wall-modeled large-eddy simulations of a barotropic convective boundary layer

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The atmospheric boundary layer (ABL) is the lowermost part of the atmosphere. Some of today's most pressing problems, including pollution, global warming, and renewable energy resource assessment, need a basic understanding of the processes inside the ABL. Thanks to the increase in computing power, progress in parallel multi-physics code, and efficient numerical model development, highly-resolved simulations of the ABL, are now feasible, enabling to use of the data obtained from direct numerical simulations (DNS) to develop and validate models of comparatively lower costs like large-eddy simulations (LES).

In this work, LES is investigated to simulate a critical stable ABL feature: spatial intermittency during turbulence collapse, when turbulent and laminar regions coexist spatially. These LES simulations are very challenging since they require a computational domain 2 to 3 times larger than the ABL height, and grid resolutions of a few meters, unlike most typical LES[1 2]. Furthermore, the boundary layer near the wall region requires a sufficiently large mesh resolution and smaller time steps to capture all its flow structures. As DNS and wall-resolved LES (WRLES) explicitly resolve the near-wall region both spatially and temporally, these techniques are computationally expensive to solve wall-bounded flows. This challenge can be addressed by the wall-modeled LES (WMLES), as it reduces the computational cost and simulation time by modeling the near-wall region[3].

This work presents a validation of WRLES and WMLES against DNS results[4] for a cloud-free convective boundary layer (CBL) over a flat and aerodynamically smooth surface at a moderate Reynolds number. The zero-pressure-gradient boundary layer is convectively forced by a constant and homogeneous surface buoyancy flux. It grows into a linearly stratified atmosphere with barotropic conditions in the free troposphere above ABL. This configuration represents a typical midday condition over land. The mesh discretization, choice of numerical method, wall-modeling, and subgrid-scale (SGS) models required to simulate such ABL flow problems are studied, using the open-source C++ code OpenFOAM. Results of various important parameters such as velocity components, momentum flux, mean buoyancy, buoyancy flux, turbulent kinetic energy (TKE) budget, and temporal evolution of various TKE components, CBL depth, and Richardson number are shown and compared with DNS results to validate the WRLES and WMLES.

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