Impact of momentum perturbation on convective boundary layer turbulence

Mukesh Kumar[1,2], Alex Jonko[2], William Lassman[3], Jeffrey D Mirocha[3], Branko Kosović[4], and Tirtha Banerjee[1]

[1]Department of Civil and Environmental Engineering, University of California
[2]Los Alamos National Laboratory
[3]Lawrence Livermore National Laboratory
[4]National Center for Atmospheric Research

April 16, 2024

Abstract

Mesoscale-to-microscale coupling is an important tool to conduct turbulence-resolving multiscale simulations of realistic atmospheric flows, which are crucial for applications ranging from wind energy to wildfire spread studies. Different techniques are used to facilitate the development of realistic turbulence in the large-eddy simulation (LES) domain while minimizing computational cost. Here, we explore the impact of a simple and computationally efficient Stochastic Cell Perturbation method using momentum perturbation (SCPM-M) to accelerate turbulence generation in boundary-coupled LES simulations using the Weather Research and Forecasting (WRF) model. We simulate a convective boundary layer (CBL) to characterize the production and dissipation of turbulent kinetic energy (TKE) and the variation of TKE budget terms. Furthermore, we evaluate the impact of applying momentum perturbations of three magnitudes below, up to, and above the CBL on the TKE budget terms. Momentum perturbations greatly reduce the fetch associated with turbulence generation. When applied to half the vertical extent of the boundary layer, momentum 1 perturbations produce an adequate amount of turbulence. However, when applied above the CBL, additional structures are generated at the top of the CBL, near the inversion layer. The magnitudes of the TKE budgets produced by SCPM-M when applied at varying heights and with different perturbation amplitudes are always higher near the surface and inversion layer than those produced by No-SCPM, as are their contributions to the TKE. This study provides a better understanding of how SCPM-M reduces computational costs and how different budget terms contribute to TKE in a boundary-coupled LES simulation.