Turbulence development assessment in a LES simulation

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Abstract:
This proposal aims to analyze conditions that allow the development of turbulence in a LES simulation with uniform initial and boundary conditions first and with conditions obtained from WRF simulations ultimately. According to recent studies [1] and considering the underlined governing equations of the simulation, a transition zone should occur over which resolved-scale turbulence is generated within the flow. This transition zone is referred to as fetch which consists of the distance into the LES domain from the inflow boundary over which the turbulence motion approach an equilibrium. Here, we assess the different fetches that arise under different conditions and configurations.

Keywords: CFD, LES, WRF, Turbulence.

1 Introduction

State of the art articles show that high resolution Large Eddy Simulation (LES) are ideal for Planetary Boundary Layer (PBL) studies [2]. However, to accurately represent the atmospheric conditions of geographic scale broader than the usual domains of microscale models like LES, it is necessary to couple the LES model with a mesoscale one, such as the Weather Research and Forecasting model (WRF) [3]. This implementation has the known problem on how to develop turbulence in the LES simulation, given that the initial and boundary conditions provided by the mesoscale model do not contain any spectrum of turbulent motion.

2 Scope

A finite volume CFD solver [4] was used to simulate a corridor-like domain in order to determine under which conditions a steady regime of turbulence motion is developed and how long the fetch is under those conditions.

A long grid of 48x1x0.5km was implemented, with uniform horizontal resolution (20m side square cells) and vertical resolution that expands with height (starting at 0.67m for the first cell). The simulations evaluate the effects of an earth's surface without topography and with realistic topography obtained from ASTER-GDEM from NASA satellite information. In addition, a uniform inflow velocity of 10 m/s and a more realistic PBL velocity profile obtained from WRF simulations were considered. The same strategy was used for the temperature field. Besides, a uniform surface heat flux was included to analyze the effects of buoyancy-driven turbulence.

Furthermore, a temperature perturbation method [5] to favor the turbulence generation and decrease the fetch is tested.

3 Results

As expected, the simulations analyzed showed that turbulence is developed with different intensities and fetches depending on the simulation conditions. For instance, in the simplest case, with just an homogeneous uniform inflow velocity, some turbulent motion starts to appear at about $24km$ from the inflow, and it reaches an equilibrium at about $29km$ (Fig. 1a). On the other hand, when a surface heat flux of about 150 W/m^2 was added, turbulence develops earlier and is stronger, starting to appear at about $5km$ and reaching a steady state at about $10km$ (Fig. 1b).

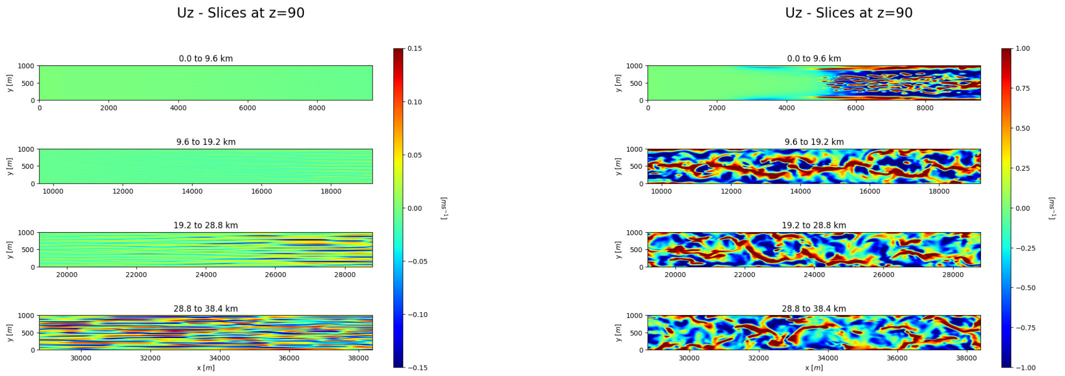

Figure 1: Instantaneous vertical velocity component at a horizontal plane $90m$ above the terrain. Each vertical subplot represents a portion of the domain in the streamwise direction. Left) simplest case Right) case with a surface heat flux of about 150 W/m^2

References

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