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LES simulations of an experimentally-produced inclined downburst: implications of a storm motion

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SUMMARY:
Downburst winds produced by an isolated stationary thunderstorm create their characteristic signatures in terms of a theoretically symmetric ring vortex and strong near-surface winds. However, there is a high likelihood for the storm to be moving rather than being stationary, which in turn changes the downburst flow features. The differences are mostly pronounced in the flow asymmetry based on the direction of storm propagation, which consequently subjects structures to different velocity profiles which affect the wind loading. To further investigate the implications of the storm motion, an experimentally-produced inclined downburst caused by the moving storm was replicated numerically. In this paper, the LES simulations of the inclined downburst were performed to focus on the full-field representation of the flow in the near-surface region. The flow field was visualized in terms of velocity contours and radial velocities were compared with measured data. Overall, the LES data show a good agreement with the measured data.

Keywords: Thunderstorm downburst, storm motion, LES simulations

1. INTRODUCTION

Thunderstorms can produce downburst winds which have the potential to endanger the integrity of low-rise structures. In the most simplified case, the downburst characteristics are defined solely by the vertical air impingement from the storm that produces the ring vortex and strong diverging winds above the surface (Fujita, 1981). However, a realistic downburst commonly includes additional contribution associated with the storm itself which is often translational instead of stationary. This contribution causes the downburst flow field to deflect from the theoretically symmetric one found in isolated stationary storms. The present work makes use of Large Eddy Simulations (LES) to support the experimental tests of an inclined downburst performed in the WindEEE Dome (Hangan et al., 2017) that aim to investigate its flow behavior due to the moving storm.

2. LES SIMULATIONS

LES simulations were performed on a computational domain replicating the WindEEE Dome with nozzle (D = 3.2 m) displaced from the chamber center (Fig. 1a). Hereby, the contribution of the storm motion was considered through the jet axis inclination angle of 30°. The average speed (U_{jet}) of 12 m/s imposed at the inlet of the domain was used to recreate the temporally and spatially correlated eddies through the synthetic turbulence generator by Poletto et al. (2013). The sub-grid scale turbulence was modeled by a dynamic method based on Lagrangian averaging (Meneveau et al., 1996). The no-slip conditions were imposed at the wall boundaries while the near-wall flow was modeled with the Spalding wall functions for smooth surfaces. Zero-static gauge pressure was prescribed at the outlet. Overall, the computational grid counted 18.2 million hexahedral cells, and the average y^+ across the bottom surface reports values greater than 30 (Fig. 1b).

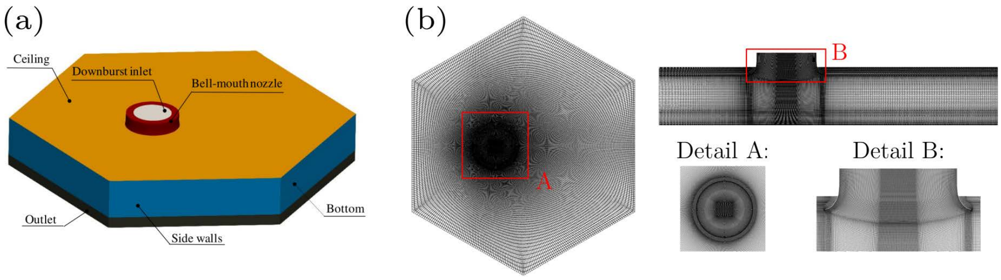

Figure 1. Computational domain with indications of boundary conditions (a), and computational grid (b).

3. RESULTS AND PERSPECTIVES

Contours of velocity magnitude plotted at the central vertical plane (Fig. 2a) show the asymmetric flow characteristics between the front and rear sides. Bigger vortex and strong winds are formed at the front side (right), compared to the rear side (left). Fig. 2b presents the time-history comparison of simulated and measured radial velocities at the selected probe location (R/D = 1.6 and z = 0.10 m) which indicates a considerable level of agreement. Further results will be presented in the full paper.

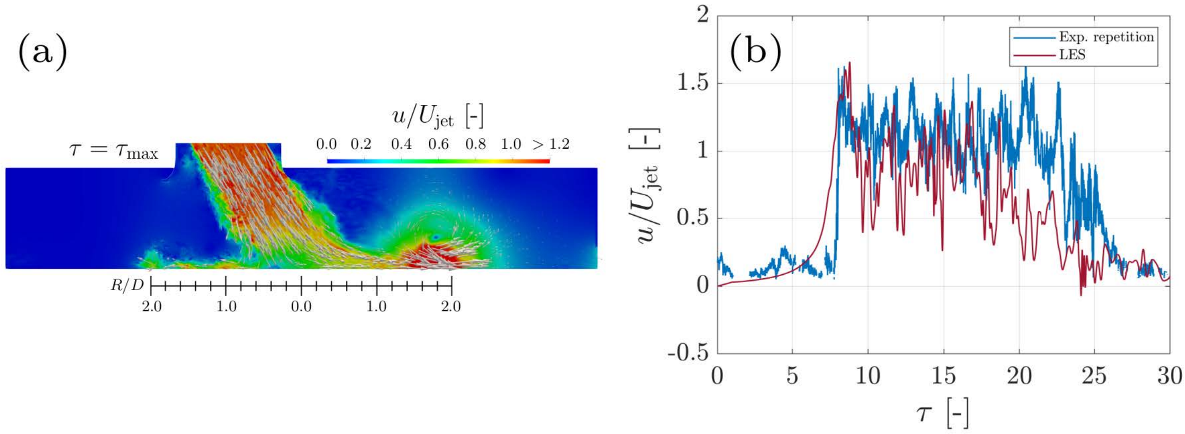

Figure 2. Results: (a) contour of velocity magnitude normalized by jet velocity U_{jet} in the time instance $\tau_{\max}$ of maximum radial outflow, (b) comparison of measured and simulated instantaneous radial velocities at R/D = 1.6 and z = 0.10 m (*i.e.* right side of Fig. 2a).

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