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Characterization of experimentally produced isolated downburst winds by Large Eddy Simulations

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1. INTRODUCTION

Thunderstorm downbursts can produce strong near-surface winds with severe consequences for low-rise structures. Due to the complex nature of the phenomenon and the lack of comprehensive full-scale recordings, downburst winds are nowadays largely reproduced as impinging jets in both experimental and computational studies in order to investigate its main physical characteristics. This is also the scope of the present study for which Large Eddy Simulations (LES) are performed to reproduce an isolated vertical downburst wind previously tested in the WindEEE Dome laboratory. The flow regions characterized by strongest wind gusts, commonly relevant for structural loading, are examined in terms of radial, vertical and temporal coordinate.

2. LES SIMULATIONS

LES simulations were performed on a computational grid representing half of the WindEEE Dome due to the imposed symmetry **(Fig. 1a,b)**. The sub-grid scale turbulence was modeled by dynamic calculation of Smagorinsky constant through Lagrangian averaging. The no-slip condition was imposed at the wall boundaries with zero static gauge pressure at the outlet. The near-wall flow was modeled with the Spalding wall functions for smooth surfaces. Inflow turbulence was synthesized by adopting the anisotropic turbulent spot method. Second-order discretization schemes were used for the equations and the PISO algorithm solver was adopted to couple pressure and velocity fields. Cell aspect ratio was kept small (less than 1.1) and the non-dimensional distance y^+ from all the walls reported average values greater than 30. The computational grid counted 16.5 million hexahedral control volumes. The LES simulations aimed to reconstruct the experimental tests of the vertical downburst for which radial velocities were measured through the test chamber of WindEEE Dome 20 times to consider repetition variability. Simulations were carried out in two different phases: (*i*) with the fixed mean vertical inflow velocity of 9 m/s at the nozzle **(Fig. 1a)**, and (*ii*) with the zero-inflow velocity (*i.e.* closed inflow through the nozzle) that allows to model the gradual dissipation of the phenomenon.

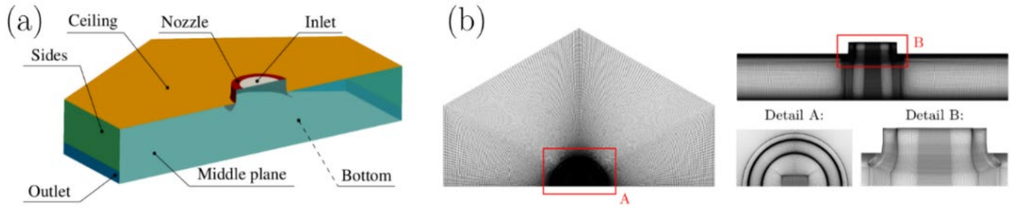

Fig. 1 (*a*) Computational domain and (*b*) computational grid of the WindEEE Dome.

3. RESULTS

LES and experimental results were compared in terms of radial velocity (u) at different R/D and a good agreement was found across the 20 repetitions. An example is provided in **Fig. 2a** for a selected probe located in the flow region commonly exposed to strong gusts (*i.e.* R/D = 1.0 and z = 0.10 m; black curve), where the red band indicates the variability of all individual experimental repetitions. Then, the LES results were used to track the maximum radial velocity (u_{max}) occurring during the event. As indicated in **Fig. 2(b,c)** u_{max} continuously changes its location (where Z_{max} is the vertical location of the overall maximum velocity U_{max}). In particular, the location of the u_{max} is associated not only with the passage and propagation of the primary vortex, but also with trailing ring vortices that keep shedding due to high levels of wind shear. Further analyses will be presented in the full paper.

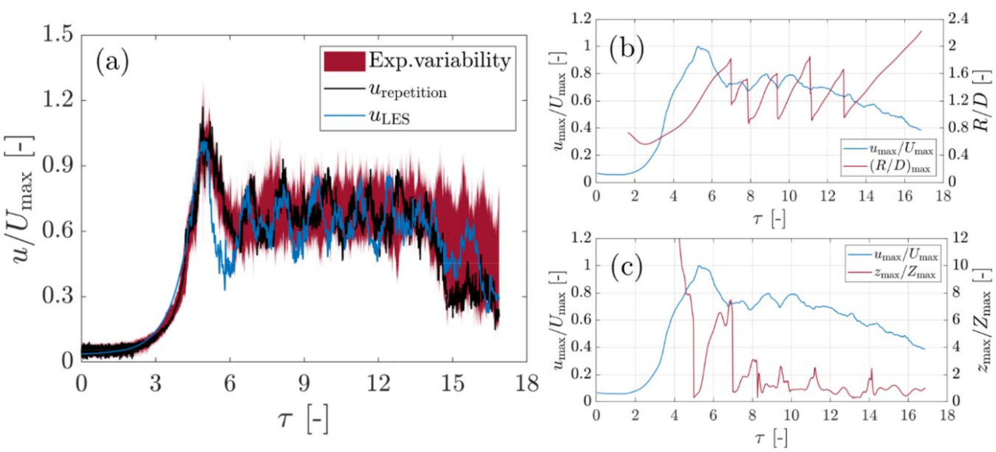

Fig. 2 LES simulation results: (*a*) time history of the radial velocity (u) and comparison with a selected experimental repetition at the R/D = 1.0 and z = 0.10 m; (*b*) time history of the maximum radial velocity (u_{max}) and its radial location $(R/D)_{max}$; (*c*) time history of u_{max} and its height z_{max}.

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