EXPLORING THE EFFECTS OF LEVEL OF DETAIL IN WIND FLOW SIMULATIONS

KEY WORDS: Level of details, computational fluid dynamics, wind flows.

1. INTRODUCTION

Climate change and urbanization are pushing the comfort boundaries of our cities, making the use of 3D city models in computational fluid dynamics (CFD) an essential part to evaluate urban layouts before construction. However, current geometries used in CFD simulations tend to oversimplify, due to lack of information or in order to reduce complexity. In this work we explore the effects of oversimplifying geometries by comparing wind simulations of different level of detail geometries. We use semantic 3D city models adjusted to their suitable use in CFD. The simulations predict wind flows in a section of the TU Delft campus, where the use of 3D model variants and semantics show how differences in geometry and surfaces affect local wind conditions.

2. GEOMETRY CONFIGURATION

Within this abstract we concentrate on two different Level-of-Detail geometries for part of the TUDelft campus, i.e. simple LoD1.3 block models and LoD2 also containing roof structures (Figure 1). The geometries were downloaded in tiles from the 3DBAG database (Dukai et al., 2021). Then, we used the open-source software cjio (Ledoux et al., 2019) to extract a few buildings and reduce the extension of our domain.

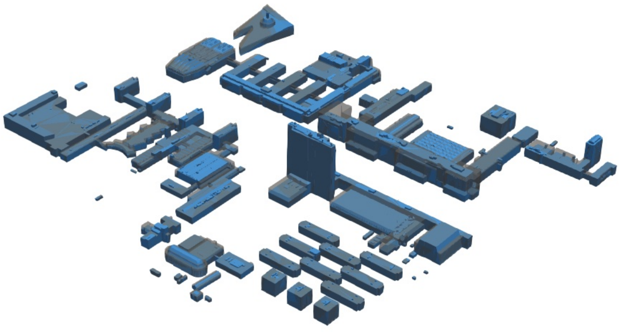

Figure 1. LoD1.3 (grey with transparency) and LoD2 (blue) geometry comparison.

3. WIND SIMULATIONS CONFIGURATION

To perform the CFD simulations we use the open-source libraries OpenFOAM, version 7 (The OpenFOAM Foundation, 2021).

3.1 Computational domain and mesh

The computational area is the extension of air around the buildings that will be modelled with CFD. This extension is defined based on best practice guidelines, that ensure that the boundary conditions pose a negligible effect in the solution at the area of interest (Franke et al., 2007). Thus, the domain extends for approximately 2x2.7km^2 in the horizontal direction, and 600m in the vertical direction. These dimensions correspond to multiples of the highest building in the test area, which is approximately 98m tall. To create the mesh, that discretizes the space around the buildings where the airflow is modelled, we used the automatic parallel mesher snappyHexMesh.

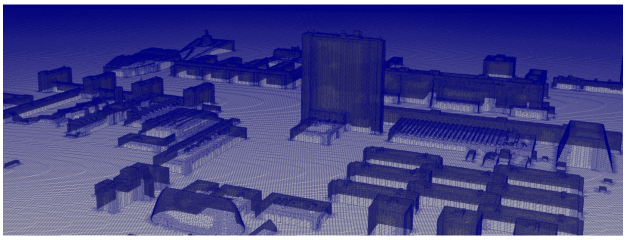

Figure 2. LoD2 mesh snapshot.

The resulting meshes contain mostly hexahedras and a few tetrahedras, with approximately 16 million cells for both cases (LoD1.3/LoD2 geometries). The cell density increases closer to building and terrain surfaces as seen in Figure 2.

3.2 Boundary conditions

We test with one main wind direction, which is causing high wind speeds next to tall buildings within the area (Kenjereš and ter Kuile, 2013). To define the velocity magnitude we used wind measurement data for the period January-October of 2019, at the Rotterdam Station (Koninklijk Nederlands Meteorologisch Instituut (KNMI), 2019). The measurements were performed at a height of 10m, and the data is averaged and introduced in our model at the same height. We assume the neutral stratification of the atmospheric boundary layer, neglecting any temperature forcing. Thus, the simulations use a logarithmic profile at the inlet, where the velocity is computed as:

$$U = \frac{u_*}{\kappa} ln\left(\frac{z+z_0}{z_0}\right), \tag{1}$$

To model the turbulence we used the k-ε turbulence model (Wilcox, 1993), setting the inflow turbulent variables, k and ε, to their consistent values through the equations:

$$k = \frac{u_*^2}{\sqrt{C_\mu}}, \tag{2}$$

$$\varepsilon = \frac{u_*^3}{\kappa\,(z+z_0)}, \tag{3}$$

where, κ is the von Karman constant set to 0.41, and u_* is the friction velocity computed by the software . We set the roughness length, z_0, to 0.5 m corresponding to a 'very rough' area with scattered buildings (Wieringa, 1992). For the buildings a smooth wall function was applied, while a rough wall function based on z_0 was used at the ground (Parente et al., 2011).

4. RESULTS

The results are presented through contour plots for wind speed, such as Figure 3, where the arrow represents the wind direction.

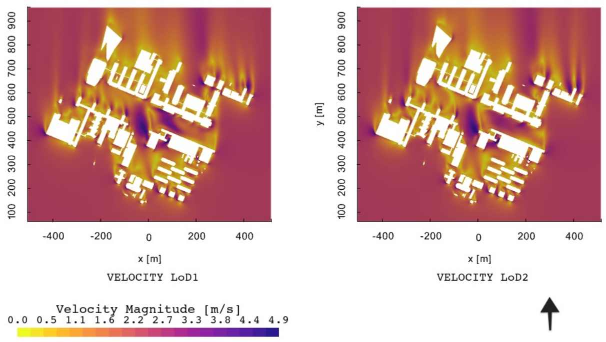

Figure 3. Velocity magnitude at 1.75m height.

Figure 4 instead presents the differences between both simulations (LoD2-LoD1.3) at 1.75m above the ground. These differences vary approximately from -3.1 to 3.3 m/s, with a few locations around the buildings, where these differences are considerable. The maximum difference in wind speed is typically found closest to tall buildings, but we also see noticeable deviations caused by low buildings differences in bottom left locations.

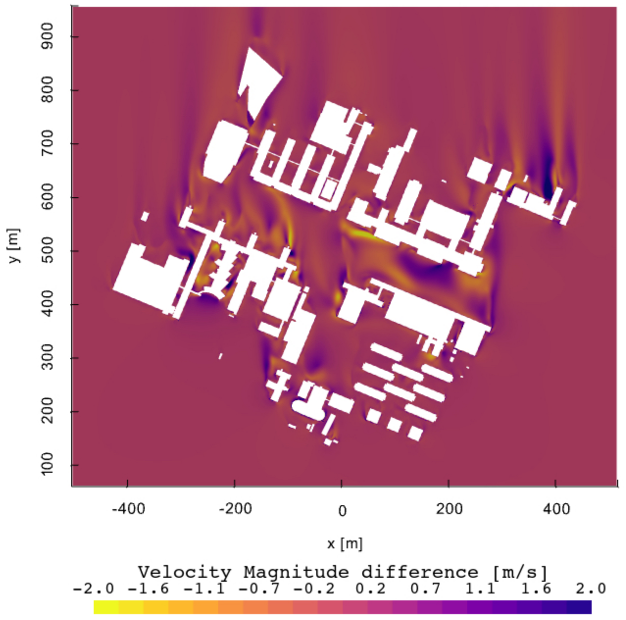

Figure 4. Velocity magnitude difference at 1.75m height.

While Figure 5 shows differences in a vertical plane within the domain. The deviations range from -3.8 to 5.9 m/s, where different heights create an increase in velocity in the most detailed geometry (LoD2). While in the street canyons we can observe how there is an increased velocity with the lowest level-of-detail geometry (LoD1.3), which is represented by a negative value in the contour plot.

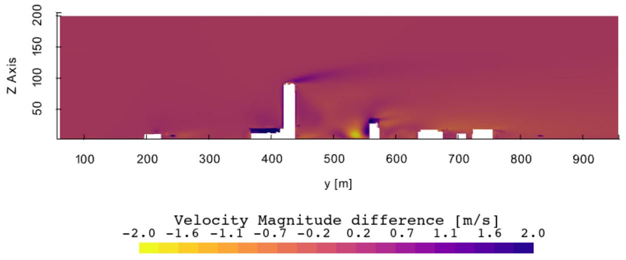

Figure 5. Velocity magnitude difference in the vertical.

We can conclude that different levels of detail leads to diverse wind patterns in built environments. This was partially addressed by other authors through specific cases (Ricci et al., 2017), while here we address it through a structured analysis. The result is relevant for wind flows, but it might be relevant for pollution or pathogens transport as well. In order to address this, further simulations including pollutant transport and with semantics will be performed for the full paper.

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