Response to Referee 2

The authors sincerely appreciate your insightful comments, which have contributed to a substantial improvement in our manuscript.

Major comments:

1. Is evaluating average wind speed sufficient to determine whether the system accurately captures complex turbulent behaviors? Shouldn't they also need to assess standard deviation and Reynolds stresses?

We sincerely thank the reviewer for this valuable suggestion. We agree that evaluating only the mean wind speed is not sufficient to fully assess whether the system can accurately capture complex turbulent behavior. Following your suggestion, we have added an evaluation of the turbulence intensities I_u and I_v in the revised manuscript to further verify the model's ability to characterize velocity fluctuations. In the revised manuscript, a new subsection "3.3 Turbulent Intensity" was added in Lines 477–508.

Specifically, for the simulation results, we first extracted the velocity components u and v at each measurement point and then calculated I_u and I_v according to the corresponding turbulence intensity formulas. For the wind tunnel experimental data, we recalculated I_u and I_v using the same time interval as the simulation results to ensure consistency and comparability in the temporal scale. Meanwhile, we added two types of figures: the vertical profile I_u and I_v between the simulation and wind tunnel experiment at observation points (**Figure. R1**), and the error distribution plots (**Figure. R2**). Here, the error is defined as "simulation result minus wind tunnel result," so an error below 0 indicates that the simulation underestimates the turbulence intensity.

The vertical profiles of both I_u and I_v turbulence intensities reveal that the FIXM configuration consistently and severely underestimates turbulence across almost all heights and inflow scenarios. This is visually evident as the FIXM results (red dashed lines in **Figure R1**) fall far to the left of the wind-tunnel measurements (blue open circles in **Figure R1**). This pronounced underestimation occurs because the static mesh relies on a priori refinement, which introduces excessive numerical dissipation in evolving wake regions and artificially smooths out critical velocity fluctuations.

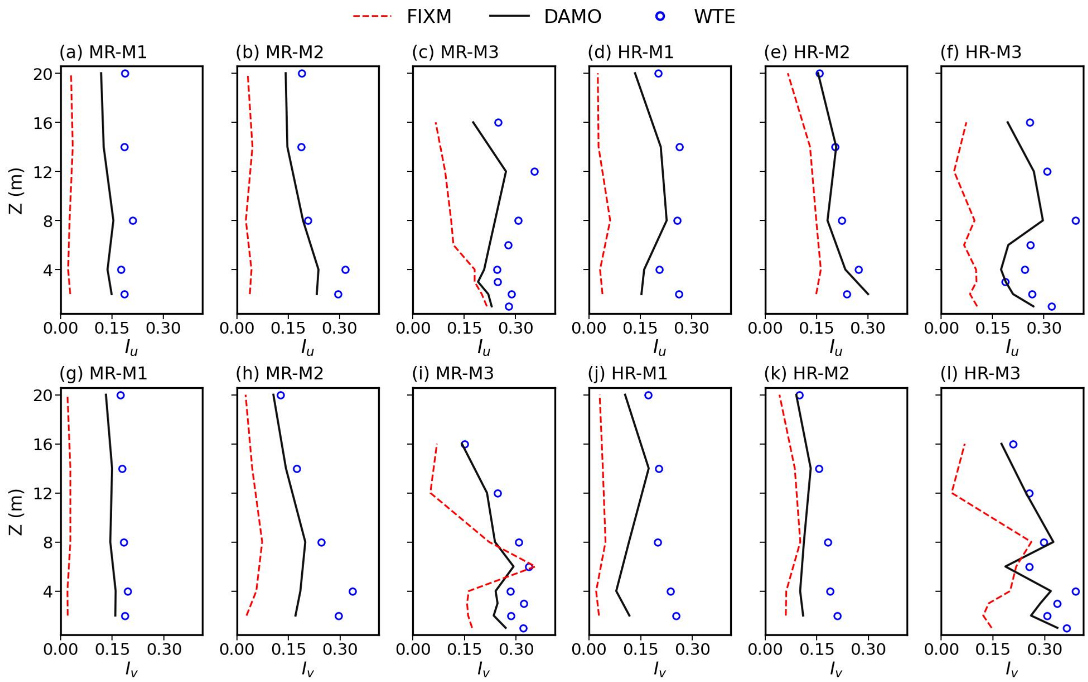

Figure. R1 Comparison of the vertical turbulence intensity profiles between the FluidUrban simulations and wind-tunnel experiments (WTE). The upper row (a–f) presents the streamwise turbulence intensity (I_u), and the lower row (g–l) presents the lateral turbulence intensity (I_v). Results are shown for the FIXM model (red dashed lines), the DAMO model (black solid lines), and the WTE observational data (blue open circles) across the medium (MR) and high (HR) roughness test cases.

Conversely, the DAMO framework (black solid lines in **Figure R1**) captures the magnitude and vertical trends of the turbulence intensity much more accurately. By dynamically tracking and refining the grid across high-gradient regions, such as separated shear layers and building wakes, DAMO explicitly resolves smaller eddies. This physical-driven allocation of computational resources effectively limits numerical diffusion, preserving the turbulent kinetic energy necessary for resolving complex multi-scale flow fields.

Figure R2 provide a robust quantitative comparison of the signed errors of I_u and I_v, where negative values indicate an underestimation relative to the observation data. While both numerical configurations exhibit overall negative biases, DAMO (red boxes) shows median errors that are consistently and significantly closer to the zero-error baseline compared to FIXM (blue boxes). Furthermore, the interquartile ranges (the height of the boxes) and the overall data spread (whiskers) are noticeably narrower and more concentrated for DAMO. In contrast, FIXM shows a more dispersed error distribution. This tighter distribution confirms that DAMO not only minimizes systematic negative bias but also yields much more stable, reliable, and spatially consistent predictions of turbulence fluctuation amplitudes across the entire complex urban morphology.

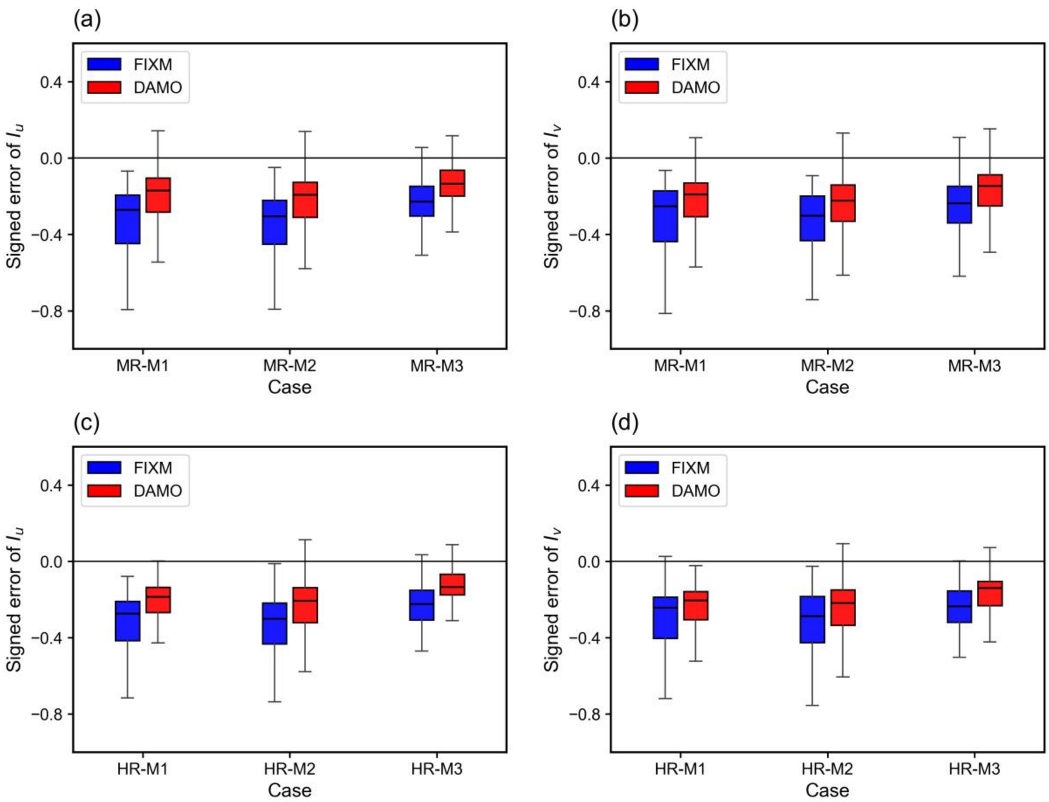

Figure. R2 Boxplots of the signed errors for the simulated streamwise (I_u) and lateral (I_v) turbulence intensities under medium roughness (MR, upper row) and high roughness (HR, lower row) conditions. For each boxplot, the box indicates the interquartile range, the horizontal line within the box represents the median, and the whiskers denote the overall data range. The solid horizontal black line marks the zero-error baseline.

Overall, although both methods inherently underestimate turbulence intensity, DAMO effectively mitigates the non-physical dissipation seen in FIXM. It successfully preserves velocity fluctuation characteristics, proving to be more robust for capturing the transient, multi-scale turbulent behaviors that dictate urban aerodynamics.

2. Shouldn't they also examine the continuity of concentration spatial distribution?

We completely agree with the reviewer that examining the spatial continuity of the pollutant concentration field is a critical aspect of dispersion assessment. Maintaining spatial continuity intuitively reflects a numerical method's ability to preserve the plume structure, which is particularly challenging in dynamic mesh models where frequent topological changes occur.

To strictly ensure the spatial continuity and mass conservation of the concentration field, FluidUrban employs two key numerical treatments. First, the scalar transport equation is discretized using a locally conservative control-volume (CV) scheme. More importantly, during the dynamic mesh adaptation process, the mapping of the concentration field from the old mesh to the newly generated mesh is executed via a conservative Galerkin projection method (Farrell et al., 2009). This rigorous mathematical treatment ensures that the frequent topological re-meshing does not introduce non-physical fragmentation, mass loss, or destructive numerical diffusion into the scalar field, thereby theoretically guaranteeing the continuity of the moving plume.

This theoretical capability is visually corroborated in the revised manuscript through the spatial concentration profiles (see Figures 16 and 17 in Section 3.4). The results demonstrate that DAMO successfully maintains a highly coherent and continuous plume structure, accurately capturing the sharp concentration gradients along the moving plume front. In comparison, the concentration distribution obtained by FIXM suffers from excessive numerical diffusion across coarser static grid regions, resulting in a significantly more smeared plume with weaker spatial continuity.

Specific comments

1. The authors should show the turbulence characteristics of LES inflow driven by a synthetic eddy method.

We sincerely thank the reviewer for pointing out the necessity of validating the inflow turbulence characteristics. We fully agree that verifying the turbulence statistics generated by the synthetic eddy method (SEM) is a crucial step to ensure the reliability of the downstream large-eddy simulation (LES).

To address this, we have extracted the vertical profiles of the inlet turbulence intensities generated by the SEM in the FluidUrban model and compared them directly against the wind-tunnel experimental measurements. As illustrated in the newly added **Figure R3**.

The comparison demonstrates that the SEM inflow boundary conditions (black solid lines) successfully reproduce the primary vertical distribution trends observed in the wind-tunnel data (red solid circles). Specifically, the SEM effectively captures the physical behavior of the atmospheric boundary layer, displaying higher turbulence intensities in the near-ground region that gradually decay with increasing altitude.

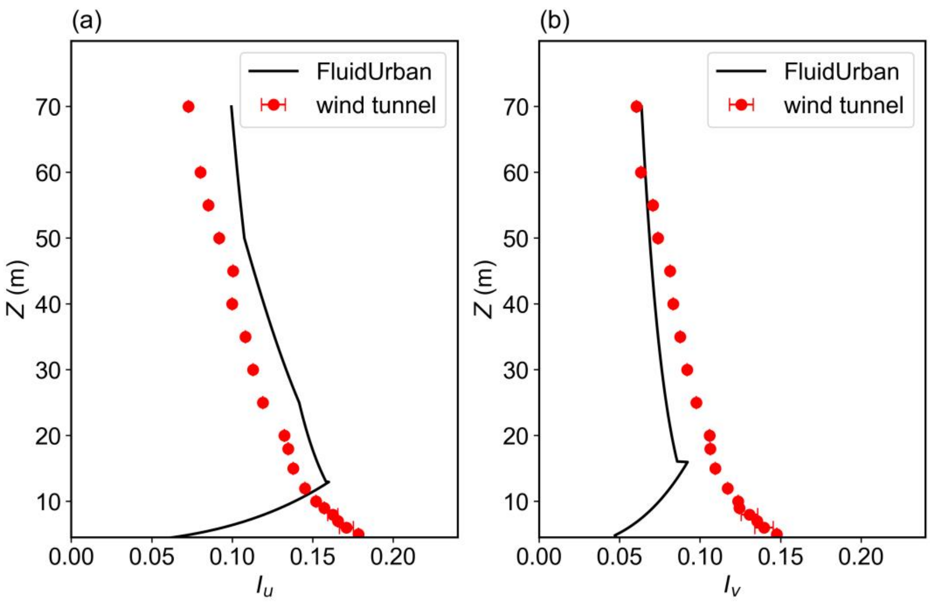

Figure. R3 Comparison of the vertical inlet turbulence intensity profiles between the FluidUrban synthetic eddy method (SEM) inlet boundary conditions (black solid lines) and the wind-tunnel experiments (WTE, red solid circles with error bars). Panel (a) presents the streamwise turbulence intensity (I_u), and panel (b) presents the vertical turbulence intensity (I_v).

In the revised manuscript, the above Figure and explanation has been added in Subsection 2.4.1 in Lines 255–268.

2. They should show spatial difference schemes for flow and scalar fields and type of subgrid models, and Turbulent Schmidt number, etc.

We agree with the reviewer that more detailed information regarding the spatial discretization schemes, subgrid-scale (SGS) model, and turbulent Schmidt number should be provided. In this study, the SGS stress is parameterised using a second-order Smagorinsky model, with the Smagorinsky coefficient set to $C_s = 0.1$ and a tensor-based filter length adopted for the anisotropic unstructured mesh. The velocity and pressure fields are discretised using a continuous Galerkin finite-element formulation, whereas the scalar transport equation is solved using a control-volume scheme. A theta method with $\theta = 0.5$ is used for time integration. Furthermore, the turbulent Schmidt number (Sc_t) is set to 0.7 to model turbulent diffusion of the scalar field.

In the revised manuscript, the above explanation has been added in Subsection 2.2 in Lines 180–185.