Feedback to the anonymous reviewer #1

The authors would like to thank this anonymous reviewer on his/her positive suggestions on the improvements over the original paper. For the the comments provided by the reviewer, the authors give the point-to-point responses as below,

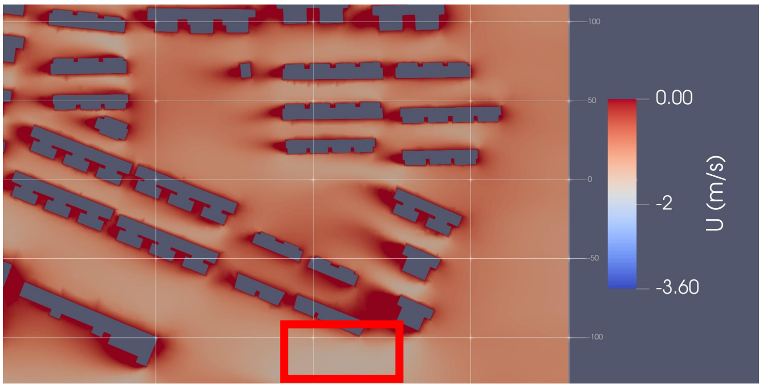
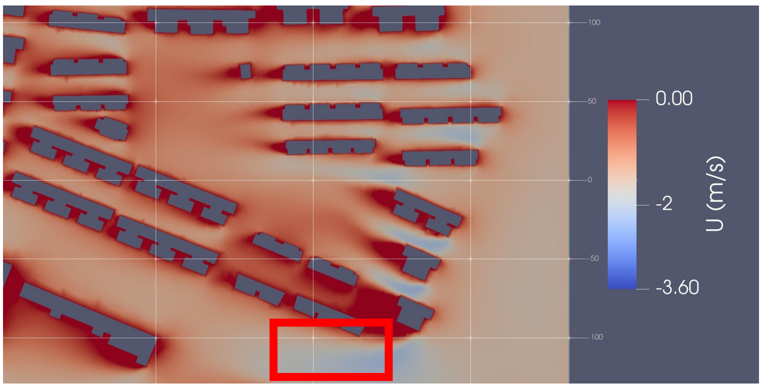
Major concerns:

1. The rationale of the WOCSS development was not clear. There are a large number of existing studies that used WRF-OpenFOAM coupling, for example, Temel et al. (2018), Li et al. (2019), and Safaei Pirooz et al. (2021). However, not much literature review regarding such application was provided in the manuscript. I'm aware that OpenFOAM has various models and features while the authors did not state why this study is novel compared to the existing WRF-OpenFAOM studies. What is the difference between WOCSS and the previous studies? Is there any existing tool for WRF-OpenFOAM coupling? These are not explicitly explained in the manuscript.

It is true that a considerable number of previous studies have been conducted to couple the simulations of WRF and OpenFOAM. The most significant advancement of the present study over the methods suggested in the literature is that the spatial and temporal variations in wind velocities and other meteorology variables are explicitly taken into consideration in coupling WRF and OpenFOAM simulations. With regards the studies explicitly mentioned by the reviewer, Temel, et al. (2018) showed the wind flows at Askervein Hill and Ria de Ferrol in Europe via coupling WRF and OpenFOAM. The boundary conditions to run the OpenFOAM simulation were, however, taken from the WRF models via a temporal average process. Pirooz, et al. (2021) coupled the meso-scale model of NZLAM to the CFD simulation with the inlet wind profile of the CFD simulation fitted from the meso-scale model results. Such a feature was also shown in the study of Kadaverugu, et al. (2021) who combined the temporally averaged WRF model results with the OpenFOAM simulation focusing on the urban wind environment of during January 11–18, 2018 over Nagpur City, India. Other than the temporal average, Li, et al. (2019) suggested coupling the WRF model with the OpenFOAM simulation via spatially averaging the WRF simulation results to provide a single wind profile at the inlet boundary of the CFD simulation domain.

The introduction of spatial and temporal variations in the data exchange between the meso-scale and micro-scale model make use of the full capacity of the micro-scale model in terms of enriching the space-time structure of the large eddies from the meso-scale simulation at the cost of dealing with data mapping and temporal interpolation at every time step for the micro-scale simulation. This is where the WOCSS stands up to play a significant role. For one thing, the spatial and temporal variations retained in the data passed to the micro-scale model at its boundary let the micro-scale model to resolve the detailed structures inside the urban boundary layer with higher resolution mesh and more advanced turbulence close schemes. For another thing, the retention of spatial and temporal variation in the data exchange requires the wind velocity simulated by the meso-scale model with relatively coarse mesh mapped onto the micro-scale model with high resolution mesh every time step. In such a case, the methods used in the previous studies (e.g. Pirooz, et al. (2021) and Kadaverugu, et al. (2021)) involving a lot of manual adjustment and supervised spatial interpolation are no longer applicable. The automatic and robust algorithms, and corresponding implementation, shown by the WOCCS therefore are helpful and valuable for conducting the coupled simulation to show the detailed space-time structures in the urban boundary layer wind field. In addition, the retention of the temporal variation means that the wind fields from the meso-scale simulation should be interpolated to drive the micro-scale simulation at the micro-scale time step. This is also the place where the WOCSS to shine as previous algorithms are usually only capable of coping with the quasi-steady state at the micro-scale side. In these so-called "snapshot" approaches, the temporal variations in the results from the meso-scale simulation are filtered with a very-large time scale. Therefore, the temporal interpolation is often neglected in the "snapshot" approach, and it is assumed that the simulation results from the micro-scale side at the previous moment (previous snapshot) has no impacts on the current micro-scale simulation. To illustrate the differences, the micro-scale simulation of the case study is repeated using the results from the meso-scale simulation at the starting moment of the coupled simulation. In other words, the "snapshot" simulation, following the methodology of Temel, et al. (2018), is conducted to compare the coupled simulation results. In addition, the results from the meso-scale simulation are fitted to the well-known profiles as suggested by Li, et al. (2019) to drive the simulation at the micro-scale side. The three simulations will be termed as "coupled", "snapshot", "profile-fitted" simulations, and their results corresponding to 60s after the starting moment of the coupled simulation are compared in Figure 1.

The manuscript will be revised accordingly to emphasize such an contribution of the present study.

coupled	
snapshot	

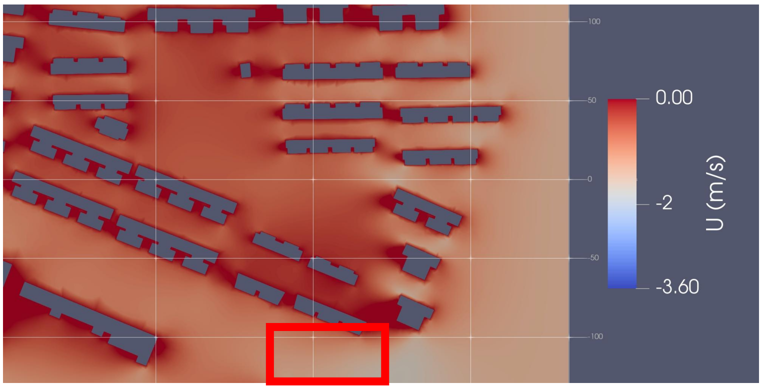
profile-fitted	

Figure 1 the comparison of the east-west wind velocity at the height of 2m

2. According to the description of the WOCSS framework, WOCSS seems to be an extension of PreCICE that only passes data from WRF to PreCICE and then to OpenFOAM, whereas PreCICE seems to play the major role in the coupling. Can the authors explain the significance of WOCSS development? Why WOCSS is such an important addition to PreCICE? Section 2 may need to be rearranged to highlight the significance of WOCSS.

It is true that the existing PreCICE library take the major responsibility for coupling the meso-scale and micro-scale simulation, mainly in the fields of data mapping and simultaneous communications between both sides. However, the PreCICE library is a set of general-purpose codes to run the coupled simulation. It is the “adapter” to various existing numerical simulation tools that makes the PreCICE library practically useful. Considering the wide application of the meteorology simulation code of WRF, the WOCSS essentially presents the “adapter” to WRF in the framework of PreCICE. For one thing, WOCSS make the WRF collaborate with other numerical tools in the simulation of cross-scale flow fields, heat transfers and other meteorological process. For example, the WRF simulation results could be used to derive ENVI-met for the assessment of the urban heat island effect via a similar approach as the WOCSS. For another thing, the WOCCS also widen the application of the PreCICE library. Currently, PreCICE mainly support the common simulation tools of fluid dynamics, structural dynamics and thermodynamics. As the WOCSS introduces the coupling of a meteorology package, other numerical simulations already built upon the PreCICE library sees the opportunity to run coupled simulation with the meteorology package.

The manuscript will be revised accordingly to illustrate the significance of the implementation of WOCSS, with regards to both the WRF model and the PreCICE library.

3. Section 3.2 Turbulence Estimation: please provide references for the estimation of the dissipation rate. Can authors clarify why Equation 1 was chosen for the estimation? There are several different methods, for example, refer to Wang et al. (2021) and Beu and Landulfo (2022).

The turbulence dissipation rate could surely be estimated from the meso-scale simulation results according to various models, and it is true that the calculation presented in the original manuscript is not superior when comparing to other available methods. Consequently, the WOCCS itself is recoded to provide the end-user the options to estimate the turbulence dissipation rate. In fact, the namelist file controls the behaviour of the WOCSS side is amended to take the option in estimating various turbulent variables. Currently, the WOCSS supports, (a) the conventional approach which utilizes the turbulent kinetic energy and length scales as in equation (1); (b) the method suggested by which requires the WRF simulation to run with certain planetary boundary layer schemes and (c) the method in accordance with several selections in the review of Wang, et al (2021), which requires the WRF simulation provides the results of turbulent kinetic energy and different types of turbulence length scales.

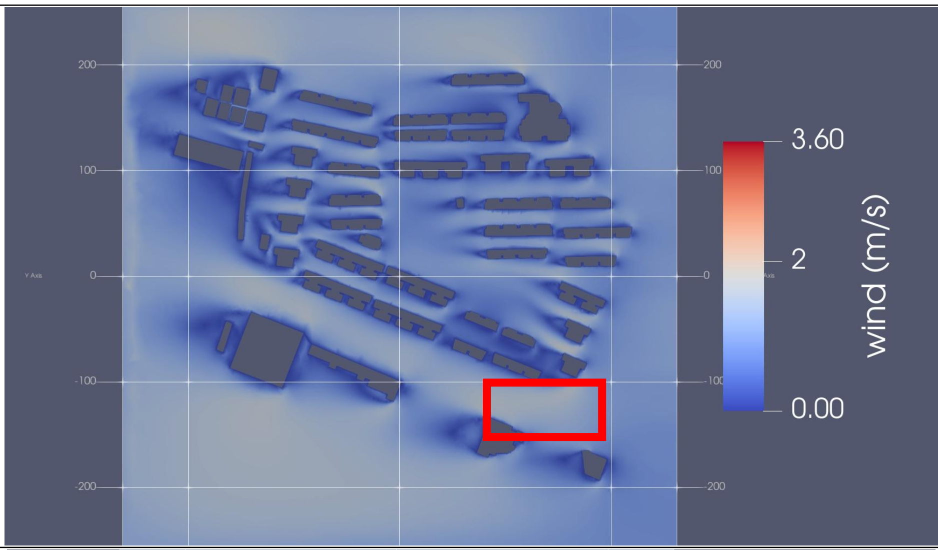
4. Case study results: only horizontal cross sections at the elevation of 51 m were presented. More analysis is required to demonstrate the difference between WRF and OpenFOAM and why the usage of WOCSS has any added value. Do the authors have observations in the simulated area? Comparison between the simulations and observations (if any) would be valuable. Also, if there is any existing tool for WRF-OpenFOAM coupling, how is WOCSS different from other tools? The presented results do not provide sufficient information to answer whether WOCSS is valuable or not.

The authors acknowledged that the value of the proposed WOCSS is not fully illustrated in the present study. More specifically, the intention of the case study reported in the original manuscript is merely showing the feasibility of running the WRF and OpenFOAM coupled simulation for a target urban area, not to show the advantages of the WOCSS. Therefore, more simulation results will be reported in the revised manuscript.

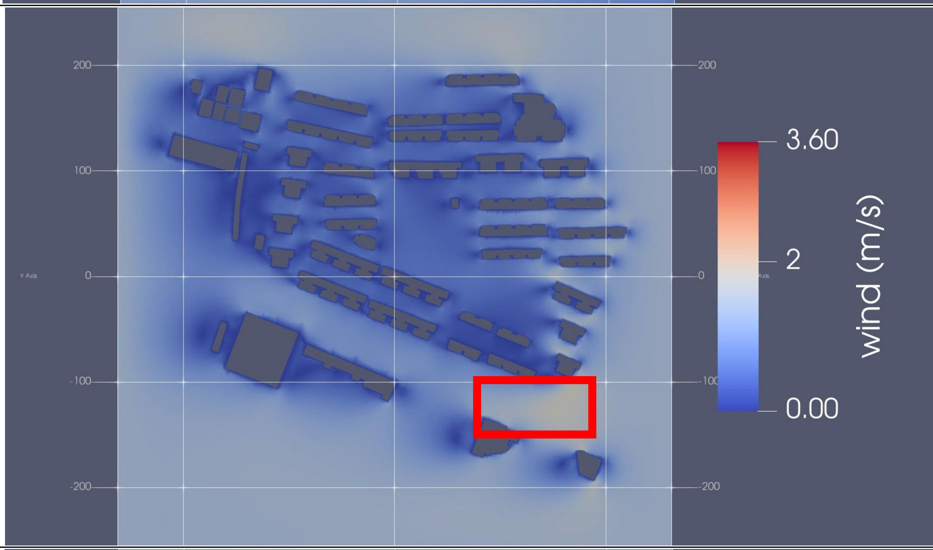
It should be noted that the accuracy of the coupled simulation inside a residential quarter relies on a variety of factors, and is not the focus of the present study. For example, the simulation at the meso-scale side relies on the planetary boundary layer and urban canopy modelling to show the realistic wind flow in the urban area. The simulation at the micro-scale side, on the other hand, are strongly influenced by the numeric differentiation schemes and turbulence models. Consequently, the comparison to the observations reveals the overall effect of the combination of various factors, and the advantages of the WOCCS could be buried. In fact, the value of the WOCSS is to provide the information otherwise not available from both the meo-scale side and the mciro-scale side. For one thing, the meso-scale simulation does not yields the detailed wind field explicitly considering the geometries of the buildings, and therefore the dangerous wind speeds threatening the safety of the building attachments, such as the speed-up effect around the building corner, are not available. For another thing, the micro-scale simulation, which yields the information with sufficient details for the assessment of building performance and pedestrian comforts, frequently run without realistic boundary conditions, which leads to unrealistic estimates of micro-scale wind field.

Therefore, the revised manuscript contains the following comparison for the purpose of substantiates the value of the WOCSS. (a) the wind fields resulted solely from the the meso-scale simulation and from the WOCSS around a building corner are compared to show that the WOCSS is able to present the corner flow due to the blocking effect of the building; (b) the wind field resulted from the OpenFOAM simulation in a steady-state with the inlet boundary conditions specified as a logarithmic profile model whose parameters are fitted from the meso-scale simulation is compared to the simulation of WOCCS, and the comparison indicates that the profile fitting, such as in the study of Li, et al. (2019), is insufficient to specify the inlet boundary conditions of the OpenFOAM if the detailed wind flow at the mid-height of the building is of interest; (c) the wind field generated by the steady-state OpenFOAM simulation with boundary conditions specified by the temporal averaged wind flow from the meso-scale mdoel is compared to the WOCSS simulation results, which reveals the effect to include the temporal variation in the WRF-OpenFOAM coupled simulation. The simulated wind velocity magnitudes at the 75s from the starting moment of the coupled simulation are shown in Figure 2.

coupled



profile-fitted



snapshot

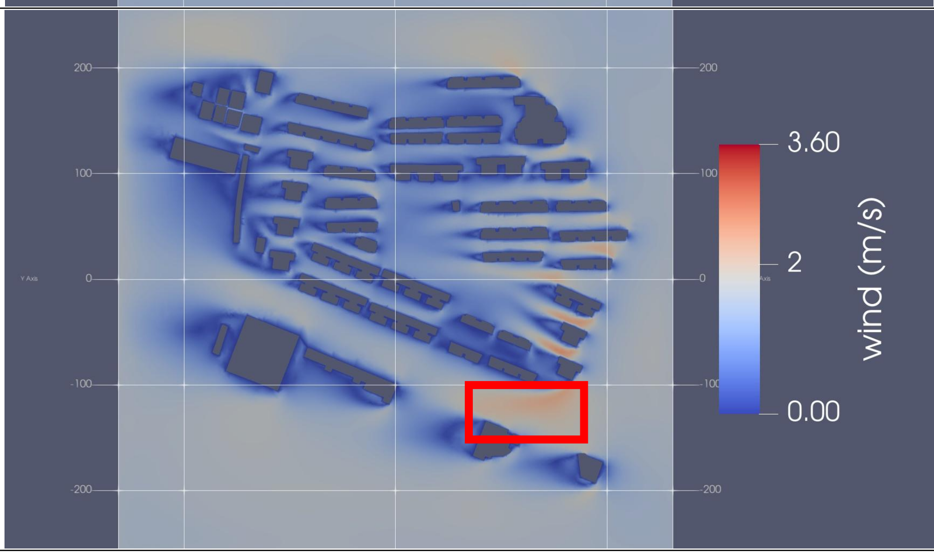


Figure 2 the comparison of the wind velocity magnitude at the height of 2m

5. Running meso-scale and micro-scale models in parallel – What is the advantage? The authors have mentioned several times that most of the current coupling frameworks do not run meso- and micro-scale models in parallel. The previous studies mostly used an “offline nesting” approach that the meso-scale model finished first and the micro-scale model will take the output from meso-scale. What is the difference between the two approaches (offline vs. in parallel)? In general, a micro-scale model runs slower than a meso-scale model. So without two-way nesting, running in parallel does not seem to provide any advantage. The WOCSS framework presented here is only one-way nesting. There may potentially be values in forecasting or nowcasting at micro-scale? More explanation is required.

To be completely honest, the parallel coupling with one-way nesting configuration only provides limited advantages comparing to the offline nesting. For the offline nesting with a relatively high resolution of the coupling interface, the data generated from the meso-scale simulation could be large if the exchange occurs after the meso-scale simulation run is finished. In such a case, the offline nesting takes additional space in hard drive comparing to the parallel coupling. In addition, reading the large data at the coupling interface into the micro-scale model takes additional computational time via communicating with the hard drive during the simulation or requires large memory to store all data at the beginning.

The true value of the parallel coupling, however, is the possibility it provided to run the two-way nesting coupled simulation. With the parallel coupling implemented in the present study, the management of running two processes corresponding to the meso-scale and micro-scale model simultaneously, and the communication between them are solved. More specifically, the mechanism for blocking one process and waiting for the coupled data and communications between two processes using the I/O widely supported by the Linux system have all been implemented. Therefore, the two-way nesting coupling, which will be the development target of the WOCSS 2.0, will be ready once the revisions are made to the source code of the WRF model to properly spread the data from the OpenFOAM simulation into its own computational domain.

Detailed comments:

1. Consistency is needed in the wordings. The authors used different wordings when referred to meso-scale or micro-scale models, which may cause confusion while reading. For example, the authors referred NWP models as “the NWP package” in the beginning of the manuscript; “the Computational Fluid Dynamics (CFD) simulation code” in Line 46 should be “Computational Fluid Dynamics (CFD) models”; and the authors mentioned “a meso-scale tool” in Line 89, while based on the concept of the sentence, it should be “a meso-scale model”. I would recommend the authors to revise these wordings throughout the manuscript.

Thank you for your constructive suggestion, the wording are revised accordingly. The revised manuscript uses the “meso-scale model” and “micro-scale model” throughout the paper except for the very beginning to point out that the “meso-scale model” is in most cases the NWP package in the field of meteorology while the “micro-scale model” is commonly the CFD simulation code.

2. CFD models are usually computationally expensive. How much computation time did the case study cost? How practical it is to use CFD models for urban climate research?

The reviewer is right about the computational cost of the CFD simulation reported in the present study is still high for practical use. In fact, the computational time of the case study using the personal computer of the authors is in the order of 10 hours. This computational cost make it inappropriate to predict the air ventilation under the emergency (such as in the case of hazardous gas leak). However, the computational cost is acceptable for research on the influence of detailed urban morphology on the localized wind field under the influence of various weather conditions. For example, the WOCCS can be used to retrace the causes of cladding damages after a strong wind event.

3. Line 94: The authors indicate that the approach used in Bakhoday-Paskyabi et al. (2022) is different from those in Lin et al. (2021) and Kadasch et al. (2021) by stating “Different from such approaches”. The threes studies all used the offline nesting approach between a mesoscale model and PALM (models did not run in parallel). Can the authors clarify the difference?

The studies of Lin et al. (2021) and Kadasch et al. (2021) only suggested the ways to read the wind data from the meso-scale simulation, and superimpose the artificial turbulence via eddy synthesizing, which could be used as inlet boundary conditions for the micro-scale simulation, but not involves the coupled simulation. In contrast, the study of Bakhoday-Paskyabi et al. (2022) presented the coupled simulation with the meso-scale model of WRF and the micro-scale model of PALM. In addition, the studies of Lin et al. (2021) and Kadasch et al. (2021) targets the micro-scale model of COSMO, but PALM. The text here is misleading, and will be revised.

4. Line 119: PreCICE was first mentioned here but no references were provided. Recommend adding citation of Chourdakis et al. (2023).

The authors acknowledge this is a flaw, and the suggested reference is added.

5. Line 128: the description of the joint simulation is quite wordy. The details should be presented in Section 2 rather than in Introduction. The authors should only present the key points such that the readers would understand that one-way nesting is used along with WRF, WRF-LES, and the CFD model embedded in OpenFOAM. Please also add references regarding WRF-LES.

The text will be abbreviated in the revised manuscript with proofreading done by a native speaker. The reference concerning the WRF-LES will be added.

6. Line 145: the authors mentioned that WOCSS is a “new framework”. What is the “old” framework and what is the novelty of this study?

The major novelty of the WOCSS framework is to introduce (a) spatial and temporal variations in wind velocities in the process of data exchanging between meso-scale and micro-scale models; and (b) running of WRF and OpenFOAM processes are in parallel with widely adopted platform of PreCICE, which enables the two-way nesting in the future. Along with the growth in the use of PreCICE, the WOCSS could go with the PreCICE

7. Figure 1: It is unclear what is the role of WOCSS here. I understand that the flowchart is for running simulations using WOCSS but both the figure and its caption did not mention anything related to WOCSS. This figure can be interpreted as a PreCICE application rather than WOCSS. Based on the description in the main text (Lines 171 to 181), WOCSS passes information from WRF to PreCICE. The resolution of the figure is quite coarse. A better image quality is required.

The figure is not clear for presenting the general architecture of the WOCSS, and will be redraw in the revised manuscript.

8. Line 196: please specify the variables and don't say "the author simply modified the official adaptor". Details are needed for readers to understand the significance regarding the development of WOCSS.

The text will be reworded in the revised manuscript and the details for the "adapter" to take into more variables (such as turbulent kinetic energy and dissipation rate) and processed for driving the OpenFOAM simulation is presented.

9. Figure 2: consider replotting and the figure caption needs rephrasing. In the figure caption, please mention the subplot labels, namely which panels are for wind velocity and which ones are for TKE. Please add dimension references (x, y, and z) in each panel. Also, the units of plotted variables are missing. Please use figures with better image quality. The figures look like combination of screenshots as the background colours are not uniform, e.g., Figures 2b and 2d look like combination of two screenshots.

The figure caption will be revised to include the descriptions of the variables of the subplots. The dimensions will be easily added to the figure as they are plotted with the software of Paraview. In addition, the units of the variables will be added to the title of the color bar of the figure as shown in this response. The quality of the figure could be damaged by the journal online submission system converting the MS WORD file into the PDF file. The figures with higher resolution will be tried to upload to the submission system.

10. Figure 3: please provide map scales.

The map scale will be added to the figure.

11. Figure 4: please provide map scales. In the figure caption, please clarify that the blocks in light green are buildings included in the case study. The buildings are not easily distinguishable from the background maps. Recommend using a more recognisable colour.

The map scale will be provided in the revised manuscript, and it will be clearly stated that the blocks shown in the figures are the buildings used for the micro-scale simulation. The buildings will be colored white in the revised manuscript.

12. Table 1: please add references for the schemes used in WRF simulations.

It is a mistake the authors have made, the appropriate references will be added in the revised manuscript.

13. Line 340: it would be interesting to outline the grid spacing of WRF simulation domains and the grid spacing or details of the mesh setup in the OpenFOAM simulation. In addition, how did WOCSS interpolate WRF grid onto OpenFOAM grid?

The grid spacing of the meso-scale model will also be summarized in Table 1 in the revised manuscript. Because the mesh is not equal-distance at the micro-scale side, the statistics of the mesh, including the grid spacing extremes will be contained in the revised manuscript. The data mapping, which interpolates the data from the WRF simulation to the OpenFOAM simulation, is controlled by the PreCICE library, and a number of different interpolation schemes are available. The corresponding configuration will be added to the revised manuscript.

14. Figure 5: please provide map scales. Please add figure label descriptions in the figure caption.

The dimensions of the buildings will be presented in the revised manuscript and the description of the subplots are added to the figure caption.

15. Table 2: please add references for the schemes used.

It is a mistake of the authors, the appropriate references will be added to the revised manuscript.

16. Figure 6: Figure caption needs to specify the details of each panel. Please use figures with higher image quality. Please increase the font sizes of axes' labels as they are hard to read in the current form. Please add spatial references of dimensions on all the right-hand side panels. I would recommend using spatial references in metres in all figures rather than using latitudes and longitudes for the purpose of comparison between WRF and OpenFOAM. And in case screenshots were used in this figure, please replot all panels as one uniform figure. What do 0 s, 60 s, and 120 s mean? Clarifications are needed. Same as Figures 7 and 8.

While the figures will be replotted as in the previous figures, the dimensions of the computational domain are added to the right panel of the figure. Using the same coordinates, the simulation results from the WRF simulation could be redrawn to show the spatial association between the WRF and the OpenFOAM results. For the time label, the actual time, not the time elapsed from the start of the coupled simulation are used.

17. Line 353: As I stated previously, the comparison between WRF and OpenFOAM was only presented at one vertical level of 51 m for wind velocities. What is the added value of this coupling? The authors need to provide more comparison, such as time series, vertical profiles, and/or hourly composites of winds and temperatures, to show the added value of using OpenFOAM. Do WRF and OpenFOAM results agree with each other? How much more information does OpenFOAM provide?

As responded above, the value of the coupled simulation will be illustrated in the revised manuscript as comparisons (1) the comparison between sole WRF simulation and the coupled simulation, focusing on the corner flow of the building; (2) the WOCSS simulation with the micro-scale simulation using wind profile fitted from the meso-scale results as the inlet boundary condition; (3) the WOCSS simulation with the coupled simulation ignoring the temporal variation.

18. Figure 8: There seems to be some artefacts (a band of very high or low values) at the lateral boundaries in OpenFOAM (right hand side subplots). While this is only mentioned in the main text, the authors may want to acknowledge such fluctuations in the figure caption.

The advice of the review will be accepted in the revised manuscript.

19. Line 366: "reliable for predicting the turbulence" – how did the authors draw such conclusions? Can the authors provide validation of the model output to prove reliability?

Such a conclusion is drawn based on that the micro-scale simulation uses more sophisticated turbulence model and finer mesh to capture the turbulent variations in the urban canopy layer. Therefore, it is reasonable to acknowledge that the turbulent kinetic energy from the micro-scale simulation is more reliable. Consequently, the agreement between the meso-scale model and micro-scale model reveals the reliability of the meso-scale model in simulating urban canopy turbulence.

20. Line 368: “the urban canopy parameterization activated in the WRF-LES scheme successfully predicts the reduction of the turbulent kinetic energy within the building cluster.” It is not surprising that a reduction of TKE is presented when the urban canopy parameterization was enabled. It is however difficult to conclude that the model results are “successful”. I would recommend the authors to present comparison between WRF, WRF-LES, OpenFOAM, and observations (if any) to show the improvements and the added values of using simulations with finer scale in OpenFOAM.

Considering the absence of the observation in the residential quarter under investigation in the present study, the simulation of the meso-scale model is compared to the simulation of the micro-scale model concerning the corner flow of the buildings. Such a feature is widely acknowledged in the building aerodynamics and in the assessment pedestrian level comfort. Since the WRF and the WRF-LES utilizes parameterization to artificially increases turbulence level according to the density and averaged height of the building cluster, the successful capture of the high level turbulence not only indicates the activation of urban canopy parameterization in WRF is necessary to evaluate the turbulence in the urban boundary layer, but also reveals the default database used by the WRF to describe the urban morphology worldwide is accountable.

21. Line 376: “Such a shortage indicates the direction for the development of the trans scale simulation framework, which is the inclusion of two-way nesting.” Any previous studies and references on this statement regarding two-way nesting?

Such a shortage is spotted out in the present study. More specifically, previous studies emphasize the importance of including the two-way nesting in the coupled simulation from the perspective of providing more accurate simulation results at the meso-scale side. The present study, however, indicates that the two-way nesting also benefits the micro-scale simulation in terms of improving the quality of the boundary conditions for the micro-scale simulation.

Minor items:

The authors would like to thank this anonymous reviewer for the correction suggestions in grammar and language, those suggestions will be taken in the revised manuscript. Following are the revisions that does not directly pertain to the language.

1. Line 31: “small-sized turbines” - please specify the size. Remove “also”.

   The turbine is installed on top of urban buildings, and therefore the installed capacity ranges from 1KW ~ 100KW. However, there has been continuous discussion on the installation of multi-MW wind turbines.

2. Line 32-34: Any references?

   Appropriate references will be added to the revised manuscript.

3. Line 35: “As for” is not a formal way to open a sentence.

4. Line 36: “at the city scale” – please specify the scale (how many meters?).

There are generally three different scales in the numerical simulations reported in the present study: (a) city scale, usually at the scale of 10km and above; (b) block scale, usually at the scale of 100m ~ 1km; and (c) building scale ~1m. Those information will be added to the revised manuscript.

5. Line 46: "the microscale model, i.e., the Computational Fluid Dynamics (CFD)". As far as I understand, microscale models include CFD, Large Eddy Simulation (LES) model, and other models. This may be a misuse of "i.e.,", which should be "e.g.," instead.

Not exactly. The authors considers the Large Eddy Simulation a branch of the CFD simulation. In other words, the micro-scale model generally corresponds to the CFD simulation, different models includes different additional variables and uses different turbulence models within the framework of the CFD simulation.

6. Line 69: Please specify what is "a geophysical scale".

This is the city scale, it will be corrected and the the information on different scales used in the present simulation are provided in the revised manuscript.

7. Line 71: Please specify "sub-building scale".

As the building scale is in the order of 1m, the sub-building scale is below 1m. The expression will be clarified in the revised manuscript.

8. Line 155-158: please add references for the sentence "The WRF model was developed by… since the 1990s".

The appropriate references will be added to the revised manuscript.

9. Line 275: Why "the horizontal bi-linear interpolation" was chosen for WOCSS?

This is because it is simple to implement, and the more advanced interpolation schemes could be developed in the future.

10. Lines 322-323: "...ERA5 dataset… in history." Please add references such as Hersbach (2019).

Thanks for the suggestion, the appropriate references are added.

11. Lines 325-335: Recommend having a separate simulation setup section for the descriptions of maps and building outlines.

The suggestion is taken and the description of the simulation set-ups and other relevant information is gathered in a separate section.

12. Caption of Figure 4: please add links/references for Bing Maps.

The appropriate link is added to the caption

13. Line 347: Is "8:00~9:00" local time? Why was this time chosen for the case study?

This is the local time, the time is chosen randomly as it is for the demonstration of the capability of the WOCSS framework, not to investigate the urban wind environment under the influence of specific weather conditions.

14. Line 361: What is "the mid-height of the building"? Does this mean any specific building in the

simulation?

This is generally at the mid-height of the building cluster, as the majority of the buildings are at the height of ~100m (30-40 stories)