Responses to reviewer1

The manuscript investigates the influence of turbulent inflow conditions on large eddy simulation (LES) of fire plume development near the ground. The authors compared simulations with uniform inflow and turbulent inflow generated by a divergence-free spectral representation (DFSR) method under two wind conditions. The topic is relevant for fire–atmosphere interaction modeling. The manuscript provides useful numerical experiments and shows that the effect of inflow turbulence becomes more significant under stronger wind conditions. It addresses an interesting problem related to LES modeling of fire plumes. The reviewer recommends minor revision, but the paper can be improved by addressing the following comments before been considered for publication.

1 The combustion process is modeled using a one-step global methane reaction combined with an eddy dissipation model. While this simplified approach is common in LES fire simulations, the manuscript does not discuss its potential limitations. The authors should briefly discuss the implications of this simplified combustion model and whether it could influence the comparison between turbulent and uniform inflow cases. Reply: Although more detailed chemical kinetic mechanism can be used, this one-step global reaction is widely used in fire modeling due to its simplicity and efficiency [1]. As such, it cannot predict complex flame dynamics, such as ignition and extinction process. It should not influence the comparison between the turbulent and uniform inflow cases. We have added this statement to the manuscript.

[1] Maragkos G, Verma S, Trouvé A, Merci B. Evaluation of OpenFOAM's discretization schemes used for the convective terms in the context of fire simulations. Comput Fluids 2022;232:105208. https://doi.org/10.1016/j.compfluid.2021.105208.

Changes in manuscript: We added a short description of this choice below Eqn. (6): "This one-step global reaction is widely used in fire modelling due to its simplicity and efficiency, but it cannot predict complex flame dynamics, such as ignition and extinction process."

2 The mesh resolution near the flame is stated to be 0.25 m × 0.25 m × 0.06 m, but the manuscript does not discuss whether this resolution is sufficient for LES of the fire plume. The authors should clarify whether any grid sensitivity test has been performed. Reply: We have performed the mesh independent test in the revised version. In the original work, we only used 2 level refinements. We further refined the meshes to 3 levels and 4 levels. Results are different between 2 refinements and 3 or 4 refinements:

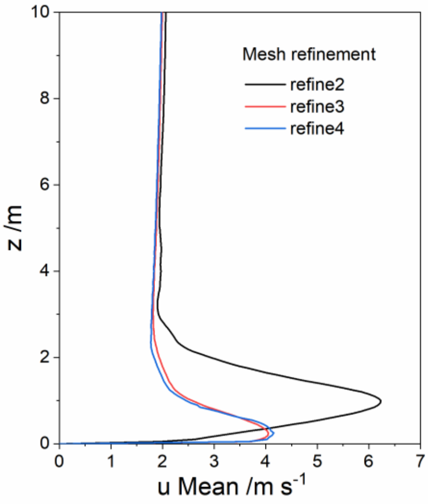

Figure Mesh independent test: Mean velocity profile at the fire front.

It can be seen that 2 refinements are not sufficient to obtain mesh-independent results, but 3 refinements are OK. Considering this, we have completely re-run all the cases and updated all the results. However, the conclusions are similar to previous results.

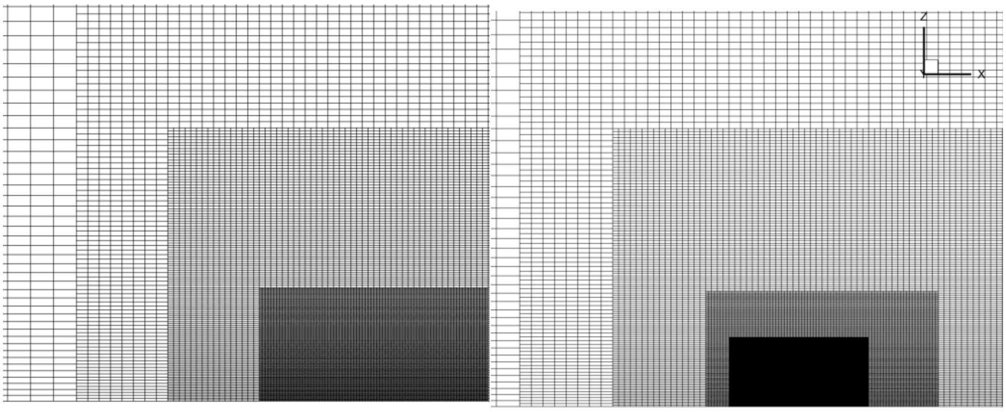

Figure 3 level refinements and 4 level refinements

Changes in manuscript: We rewritten the mesh information at the paragraph above Figure 1:

"The mesh consists of four level grids, as shown in Figure 2. The first level is adopted for the whole domain, the second level is used between (30, 26,0) and (70, 54, 32), the third level is used between (34, 34,0) and (60, 46,12), and the fourth level is used between (38, 37,0) and (48, 43, 5). This refined mesh leads to a mesh size of 0.125 m in x direction, 0.125m in y direction and 0.03m in z direction. The total number of mesh is about 3.79 million."

3 About the averaging time, the averaging period used for statistical analysis is 240 s, which corresponds to approximately 3–8 flow-through times depending on the wind speed. This averaging window may be relatively short for obtaining statistically converged mean fields in LES of atmospheric flows. The authors mention that the averaging time is sufficient for plume statistics, but no quantitative evidence is provided.

Reply: Following figure shows the effect of ending averaging time for the TKE distribution. It is clearly that the TKE changes little after 450s, which means 240s averaging is sufficient.

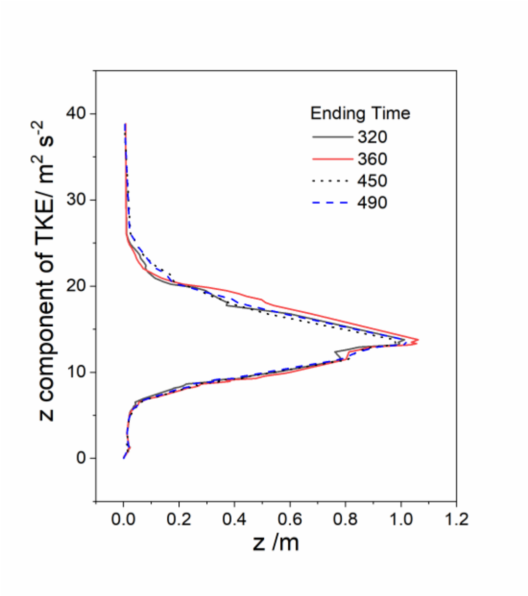

Figure Time averaging window effect

Changes in manuscript: We did not change anything in the manuscript.

Minor comments:

The captions should specify whether the plotted quantities are time-averaged or instantaneous.
“Form Figure 4”, should be “From Figure 4”
Temperature unit in Figure 13 is missing
Legends in Figure 15 are not consistent, and some are two small.
Reply: We have revised these mistakes.

Changes in manuscript:
We change the capture of Figure 4 by adding “Mean”: “Mean velocities fluctuations 2 m before the fire source under different conditions.”
We added units for Figures 5-15.
We completely reproduced Figure 14 and 15 for better visualization effect.

Responses to reviewer2

This manuscript addresses a critical research gap in fire plume LES modeling by investigating inlet turbulence effects under weak/moderate wind conditions, and the research topic has practical academic value for fire plume modeling. The numerical methodology is described in detail, the results are adequately analyzed and supported by sufficient data. However, the numerical methodology verification is not sufficient, and it requires more comparison and analysis.

(1) Why is the DFSR method is used? The authors should justify the choice and discuss its validity in generating turbulent ABL.

Reply: As discussed in the introduction section (From line 26-32), there are many ways to generate turbulent ABL for wind simulation, such as the precursor-successor method and the synthetic method. The DFSR method is designed for wind engineering computations and should also apply for current work. Its validity for turbulent ABL has been discussed in its original paper (Melaku and Bitsuamlak 2021) and is not discussed in this work.

Changes in manuscript: We added the sentence in section 2.2 “whose validity for turbulent ABL has been discussed in its original paper (Melaku and Bitsuamlak 2021) and is not discussed in this work.”

(2) Add mesh sensitivity analysis (at least 3 resolutions) with quantitative comparison of key plume parameters (centerline T/velocity, TKE, etc.), and clarify grid convergence and selection rationale.

Reply: We have performed the mesh independent test in the revised version. In the original work, we only used 2 level refinements. We further refined the meshes to 3 levels and 4 levels. Results are different between 2 refinements and 3 or 4 refinements:

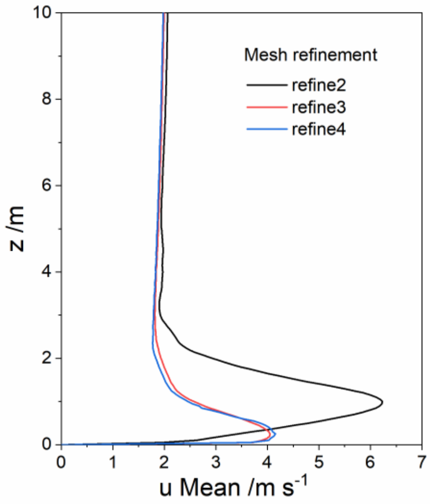

Figure Mesh independent test: Mean velocity profile at the fire front.

It can be seen that 2 refinements are not sufficient to obtain mesh-independent results, but 3 refinements are OK. Considering this, we have completely re-run all the cases and updated all the results. However, the conclusions are similar to previous results.

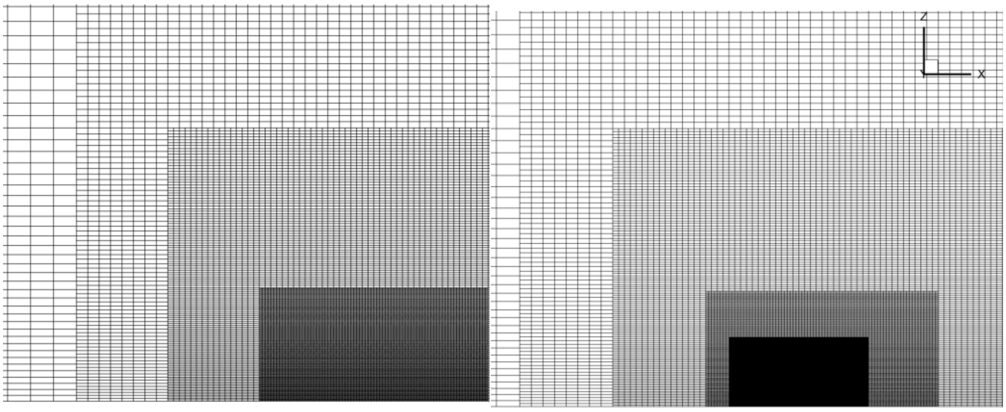

Figure 3 level refinements and 4 level refinements

Changes in manuscript: We rewritten the mesh information at the paragraph above Figure 1:

"The mesh consists of four level grids, as shown in Figure 2. The first level is adopted for the whole domain, the second level is used between (30, 26,0) and (70, 54, 32), the third level is used between (34, 34,0) and (60, 46,12), and the fourth level is used between (38, 37,0) and (48, 43, 5). This refined mesh leads to a mesh size of 0.125 m in x direction, 0.125m in y direction and 0.03m in z direction. The total number of mesh is about 3.79 million."

(3) Provide quantitative time-averaging convergence verification (convergence curves of key statistics with averaging time) and explain the 250 s averaging start time.

Reply: Following figure shows the effect of ending averaging time for the TKE distribution. It is clearly that the TKE changes little after 450s, which means 240s averaging is sufficient. We choose the 250 s as the averaging start time because the 50 second is usually enough to exclude the effect of the initial state on the flame temperature averaging.

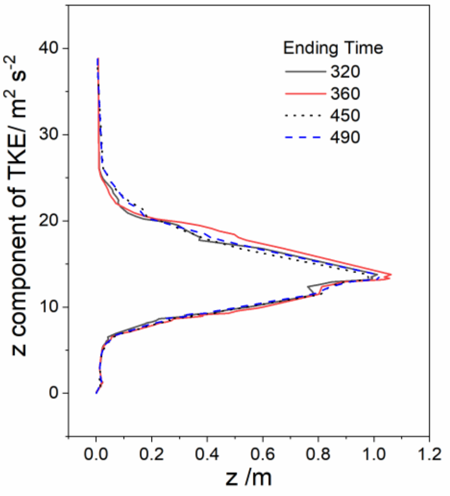

Figure Time averaging window effect

Changes in manuscript: We did not change anything in the manuscript.

(4) Justify the models used in the work (SGS model, combustion model, radiation model, etc.) and provide the missing key model parameters (EDM empirical constants, SGS model coefficients, and so on.).

Reply: These models can also influence the results of the temperature, velocity and turbulent energy. Some of their influences have been investigated by some authors. Such as:

Maragkos G, Merci B (2020) On the use of dynamic turbulence modelling in fire applications. Combust Flame 216:9–23. https://doi.org/10.1016/j.combustflame.2020.02.012

Sun Y, Yu Y, Chen Q, et al (2022) Flow and thermal radiation characteristics of a turbulent flame by large eddy simulation. Phys Fluids 087127: https://doi.org/10.1063/5.0107876

The choices of these models have been validated by above references and those cited therein. Hence, we did not repeat the validations in this work as our focus is the turbulent effect. All the model constants can be views in the uploaded openfoam files. However, we also cited a reference for the convenience of the readers.

Changes in manuscript: We added a reference for all the model parameters at the end of the paragraph below Figure 4.

(5) Calculate non-dimensional numbers (Fr/Ri) to quantify the buoyancy-inertial force balance and explain the differential effect of inlet turbulence under 2/5 m·s⁻¹ wind speeds.

Reply: For both conditions, the maximum temperature T can be around 2200K, and the environmental temperature is 300K. We chose the Froude number:

$$Fr = \frac{U}{\sqrt{g'L}} = \frac{U}{\sqrt{g\frac{T-T_\infty}{T_\infty}L}}$$

The Froude numbers are about 0.179 and 0.449 for 2ms-1 and $5ms^{-1}$ respectively, indicating the stronger wind inertial force for the latter case, leading to more inclination of the flame for the $5ms^{-1}$ case.

Changes in manuscript: We think that above analysis do not provide insightful information for explaining the balance between the buoyance and inertial force as the Fr is proportional to velocity for this study, so we chose not to add this to the manuscript.

(6) The authors should provide more information about the turbulent fluctuations in Figure 4. Why are the fluctuations much larger for 5ms-1 case?

Reply: As we stated in the paper: We collected the mean velocity profiles and turbulent fluctuations at a location before the fire source. The exact location is 38m, 2m ahead of the fire. They are larger for the 5ms-1 case because we used a similar turbulent intensity (which is the ratio of root square of turbulent fluctuations to the velocity) for both cases.

Changes in manuscript: We changes the capture of figure 4: "Mean velocities fluctuations 2 m before the fire source under different conditions." and figure 3: "Mean streamwise velocities 2 m before the fire under different conditions. "uniform" means uniform inflow condition, "turb" means turbulent inflow condition."

Adding an explanation for the larger fluctuations of the 5ms-1 case at the end of paragraph above figure 3: "From Figure 4, velocity fluctuations of the 2 m s^{-1} case are less than 0.03 m^2 s^{-2}, and are less than 0.24 for the 5 m s^{-1} case because we used similar turbulent intensities for both cases."