Response to the reviewer

We thank the reviewer #2 for their useful comments and the time invested in reviewing our manuscript. We have addressed each of the referee comments as detailed point by point below, which we believe has significantly improved the quality of the manuscript.

Reviewer 1

Main Comments

Reviewer Point P 1.1 — From reading the article, one can not know precisely what TKE models parameters were used in the simulations. As an example, the $k-\varepsilon$ model can use different model constant values such as C_μ used in the calculation of the turbulent viscosity $\mu_T = \rho C_\mu \frac{k^2}{\varepsilon}$. Is is usually used the standard value $C_\mu = 0.090$; however, for atmospheric flows $C_\mu = 0.033$ seems to be more adequate. Is that the case? There are also other parameters that are not revealed, such as the Prandtl number for the turbulent dissipation and others. Do you use the default values in OpenFOAM? Even if it is the case, it should be enumerated.

Reply: Indeed, this is an important point, we thank the reviewer for highlighting this missing information. All the TKE models parameters that were used in the simulations are now enumerated in Table 3 in the manuscript. For the Canopy model, the $k-\epsilon$ turbulence model utilized had a coefficient $C_\mu = 0.033$, however, for the other models the default coefficient of $C_\mu = 0.09$ was utilized. Other constant values such as the Prandtl number for the turbulent dissipation are also defined in Table 3.

Table 1: Turbulence constants for different turbulence models

Coefficient	**Turbulence model**			
	SKE	MKE	KO	KE-Lim
C_μ	0.09	0.033	0.09	0.09
C1	1.44	1.44	-	1.44
C2	1.92	1.92	-	1.92
σ_ϵ	1.30	1.85	-	1.30
σ_K	1.0	-	0.5	-
α_K	-		0.5	-
α_ω	-	-	0.6	-
$\beta*$	0.09	-	-	0.09
β	-	-	0.072	-
ν	1.5e-05	1.5e-05	1.5e-05	1.5e-05
L_{max}	-	-	-	62.14
k_{Amb}	-	-	-	0.001
ϵ_{Amb}	-	-	-	$7.208e-08$
T_{Ref}	-	-	-	300
Pr	-	-	-	0.9
Prt	-	-	-	0.74

Reviewer Point P 1.2 — A similar problem appear in the canopy model description; the model parameters aren't completely defined. It is said that the model is based in [Lopes da Costa, 2007], but this model uses several parameters that are not fully addressed in this article. It is presented the source term for the velocity and one can not know what is the α parameter in it or what that represents. The source/ sink terms for the turbulent kinetic energy and its dissipation rate are not also mentioned. I think that you might be more clear in this subject.

Reply: Indeed, we thank the reviewer for pointing out this missing information. The canopy model description has been updated in the revised manuscript. We apologize for the inconsistency in the parameter definitions, this has now been corrected throughout the document. The canopy source term was utilized with the simpleFoam flow solver. The porosity model is based on the"powerLawLopesdaCosta" model implemented in OpenFOAM [1]. It is a variant of the power law porosity model with spatially varying drag coefficient. This source term is applied to the momentum equation to reproduce the momentum dissipation that the trees and its foliage should produce in the flow. The following parameters are used: Porosity surface area per unit volume or the leaf area density ($\Sigma = 1.0$), Drag coefficient ($C_d = 0.25$), and the Power law model exponent coefficient ($C1 = 2.0$). The $k - \epsilon$ turbulence model utilized with the canopy model uses the following model constants as enumerated in Table 3 in the manuscript. These details have been added in the Methodology section of the manuscript (Section 3.2).

Constant	Value
C_{mu}	0.033
C1	1.44
C2	1.92
σ_{eps}	1.85

Alternatively, there are canopy source terms that can be utilized buoyantBoussinesqSimpleFoam solver. These included the atmPlantCanopyUSource, atmPlantCanopyTSource, atmPlantCanopyTurbSource for momentum, temperature and turbulence respectively, taking into account the thermal and turbulence effects induced the canopy into account. The source/ sink terms for the turbulent kinetic energy and its dissipation rate have not been utilized for the present study on a complex terrain, as we encountered convergence issues that needs to be resolved.

Reviewer Point P 1.3 — In chapter 3 , though the definition of the domain volume is well explained, the description of the computational mesh is vague. It is said that it consists in 12.7 million cells, but it would be more useful to define it by the number of cells per main direction, such as $n_x \times n_y \times n_z$. It is said that the horizontal mesh resolution was set to 33 m, but is this resolution observed only in the center of the domain (close to the masts location) expanding itself to the boundaries or is it a regular mesh? (...which is probably not the case, as the domain is not square or rectangular, but cylindrical.) It is also said that an "uniform stretching is applied to the vertical direction" with no more details. However, one of the most important mesh parameters in an atmospheric flow simulation is the minimal mesh height Δz next to the ground (along with the vertical number of cells), which is not presented in the article.

Reply: Indeed, we apologize for the incomplete description of the computational mesh, it is now specified as follows in the revised manuscript. The overall mesh consists of 12.7 million cells. In terms of the number of cells per main direction ($N_x \times N_y \times N_z$) the mesh comprises of 227 x 227 x 120 across the terrain patch. The minimal mesh height Δz next to the ground is close to 3 m. The vertical mesh resolution is 33 m, with a stretching factor applied to cluster cells close to the ground as seen in Fig 4 in the manuscript. The terrainBlockmesher [3] tool uses a blending function to smooth the transition from the terrain patch to the outer cylindrical block. Around 50 radial block cells are defined and a radial grading factor is used to enable a stretching in the horizontal direction to cluster cells across the centre of the domain (close to met mast locations) and expanding towards the boundaries. This description has been updated in the Methodology section of the manuscript (Page 5).

Reviewer Point P 1.4 — It is said (line 145) that you have choose a mean tree height of 3 m. I suppose that it is all over the domain (or, at least in the $7,5$ km$\times$ 7.5 km squared area - it is not clear in the article. Wouldn't it be more correct to use different patches (eventually with different heights), as you have that information in figure 5? Or, at least remove the trees from the higher zones of the ridges, as it is common to happen in this kind of topography and cam be observed in figure 5?

Reply:
We agree with the reviewer on this point. It would be more correct to use different patches with different heights as seen in the forest point cloud data. We choose a mean tree height of 3 m applied all over the domain. A cell set was utilized to select a volume of cells 3 m above the ground (this forms a canopy zone where the source terms are activated). This description has been updated in the article in Section 3.2. Indeed this can be modified to be more specific in the choice of areas to activate the canopy model. This requires a use of a function that interpolates data from the forest point cloud for selection of canopy height for each point on the terrain patch, which is presently being coded.

Reviewer Point P 1.5 — I suppose that you use in the canopy model an uniform area density. However, forests have a higher foliage density at the half top than at the bottom zones - [Lalic and Mihailovic, 2004]. I think a non-uniform leaf area density could be easily implemented in that model.

Reply:
We thank the reviewer for this suggestion. Indeed, as highlighted by Lalic and Mihailovic [2], forests have a higher foliage density at the half top than at the bottom zones. The objective of this study was to study the influence of canopy, and to test if the use of a canopy model could improve predictions close to the ground with uniform area density. Future simulations can be performed with a non-uniform leaf area density based on an analysis of the foliage composition in Perdigao [4].

Reviewer Point P 1.6 — I find the Figure 13 very interesting. The extension of the slice could be wider, in order to include the whole top of the ridges and clearly show the positions of the masts 10 and 7 (and approximately the zone of mast 37). This small change could complement and be more enlightening in the interpretation of the results obtained for these masts and presented in the other figures. (Also could be useful for the reader if the caption of the figure refer that the location of slice is defined in Figure 2.)

Reply: Thank you for this very valuable suggestion, which we have taken into account by updating Figure 15 and also Figure 2 accordingly. The captions have also been updated and other relevant captions, referring to the location of the slice and masts 10, and 7 and (approximately the zone of mast 37) in Figure 2.

Minor

Reviewer Point P 1.7 — Line 111: "..homogeneous atmospheric boundary layer (ABL). either..." should be "...homogeneous atmospheric boundary layer (ABL) either...".

Reply: This typo has been correct in the manuscript. Thank you for the suggestion.

Reviewer Point P 1.8 — Figure 5: The scale in the figure is strange; the sequence of the $d($ m$)$ values is $0, 2, 6, 4, 8$; shouldn't it be $0, 2, 4, 6, 8$? 3. For example: In Figure 5, m for meters shouldn't be written in italic as it is not a variable, but a length unit. In many other figures there is also the variables $(U, TKE, \ldots)$ not in italic, but with the units in italic; it should be the opposite.

Reply: Thank you for the suggestion. Yes, the sequence of the bar values was wrong an have now been fixed. Figures with variables and units in wrong text style regarding italic/non-italic has been fixed. It includes Fig. 2, Fig. 3, Fig.5. 6-14 and 16-22

Reviewer Point P 1.9 — Table 2: I would prefer the description of each case to be done in a more clear way, instead of using "-"- " all over the table.

Reply: Table 2 has been fixed in the manuscript with all the columns clearly written. Thank you for the suggestion

Reviewer Point P 1.10 — Line 111: "predictions" is two times written.

Reply: The typo has been fixed. Thanks for the suggestion.

Reviewer Point P 1.11 — Line 205 to 206 : I think that the order of the towers and the figures is somehow messed up. It should be "...towers 25, 7, 27 and 22.", and further, "...shown in Figs. 9, 10, 11 and 12 respectively.".

Reply: This has been fixed. The figures have been regrouped in terms of group of masts for a specific variable.

Reviewer Point P 1.12 — ...and a small detail: in the references, "Costa, J. L. C. (2007)" should be "Costa, J. C. L. (2007) ", or even "Lopes da Costa, J. C. (2007)$''$. ;)

Reply: This has been fixed. We apologize for the oversight.

References

[1] *API guide: powerlawlopesdacosta class reference.* URL: `https://www.openfoam.com/documentation/guides/latest/api/classFoam_1_1porosityModels_1_1powerLawLopesdaCosta.html`.

[2] Branislava Lalic and Dragutin Mihailovic. "An Empirical Relation Describing Leaf-Area Density inside the Forest for Environmental Modeling". In: *Journal of Applied Meteorology - J APPL METEOROL* 43 (Apr. 2004), pp. 641–645. DOI: 10.1175/1520-0450(2004)043<0641:AERDLD>2.0.CO;2.

[3] Jonas Schmidt, Carlos Peralta, and Bernhard Stoevesandt. "Automated generation of structured meshes for wind energy applications". In: London: Open Source CFD International Conference, London, Oct. 2012.

[4] C.A.M. Silva et al. "Surface cover in Perdigão: forest delineation - 2nd Workshop on Perdigão". In: Mar. 2019.