**Anonymous Referee #3**

**The authors apply the WRF-Chem model to simulate coarse and giant dust (besides the fine dust). For this purpose, they modified the dust transport bins in WRF-Chem, applied a modified (observations-derived) pre-defined particle-size distribution (PSD) to dust at emission and also modified the settling velocity to be applicable beyond the Stokes regime. With their modified model version, they conduct sensitivity runs with reduced settling velocities to test the impact of settling velocity compared to aircraft dust observations.**

**The study is timely and interesting, but I see two major weaknesses, one related to the comparison with observations and the other related with the transfer of the simulation results to processes other than settling velocity. I detail those aspects below besides other specific comments.**

**While the manuscript is overall well organised (although I suggest some changes, see below), grammar and orthography need to be improved throughout the manuscript.**

We would like to thank the reviewer for taking the necessary time and effort to review our manuscript. We sincerely appreciate all your valuable comments and suggestions, which helped us in improving its quality. We have put a lot of effort on improving grammar and orthography issues in the revised manuscript and we tried to incorporate all the changes to reflect the provided suggestions.

**Main comments:**

**The authors distribute the total emitted dust mass (all sizes) across their new bins using a prescribed PSD obtained from aircraft observations (FENNEC-PSD) at 1 km altitude. Given that particles**

**settle when they are airborne (even if less than expected), the actual PSD at emission has to have been coarser than that observed at 1 km. It is still possible technically and no issue to apply this observed PSD at 1km to the emissions. However, in Fig. 5 / Section 3.2 / Section 3.4 / Discussion, the authors compare the modelled PSD at 1, 2, and 3 km height with the mean FENNEC PSD at 1km height and conclude that the model underestimates coarse dust, even when the settling velocity is reduced by 80 %. This is only natural as the FENNEC-PSD has been used at the PSD at emission, hence the model could only ever reproduce the observed PSD at 1km if all the emitted dust would be transported to 1 km in the model without any sedimentation.  the model has no chance to do so. If this is the goal, then the PSD at emission would need to be described as coarser than the FENNEC-PSD, possibly by assuming a certain settling rate. In the context of the comparison between modelled PSDs and those observed in AER-D, I would like to see a specific comparison between the AER-D PSDs, the FENNEC-PSDs (this could in principle be seen from Figures in the paper, but a direct comparison would make this much easier): Are those PSDs, which have been measured above (FENNEC) and distant (AER-D) to dust source regions "sufficiently" distinct (i.e. is the FENNEC-PSD, which has been used for the emission, "sufficiently" [whatever this means] coarser than the AER-D PSD), such that the model has a chance to reproduce the after-transport AER-D PSD? I believe this aspect is critical, because it might well be that settling is one, but not the only key problem, but that particle sizes at emission are considerably underestimated, even if using the FENNEC-PSD. Besides this general discussion, I would like to ask how the part of the FENNED-PSD, that extends beyond 100 microns, has been dealt with when distributing the emissions. Was this fraction ignored and the remaining PSD re-normalized?**

The reviewer raises an important issue on the impact of the size distribution which is used for the parameterization. Let us first mention that the critical information that passes into the model, and it is derived from the "fitted FENNEC PSD", is the PSD shape and not its exact magnitude. We use only the part of FENNEC-PSD between 0.2 to 100μm in diameter, which is normalized, after ignoring the remaining part that extends below 0.2 μm and beyond 100μm.

With regard to the question about whether the FENNEC PSDs are significantly different to those from AER-D, in order that the model has a chance to demonstrate the appropriate downwind changes in dust PSD: A comparison of the PSDs between FENNEC and AER-D is given in Ryder et al. (2019) Figure 2. There, the differences between the FENNEC and AER-D are around a factor of 10 at 20 microns diameter, and nearly a factor of 100 at 60 microns diameter. Note that this figure shows the Fennec mean, rather than the low-altitude fresh PSD used in our study, which contains an even stronger contribution from the coarse and giant size ranges, such that the differences will be even greater. Therefore, there is ample scope for the model to demonstrate an (in)ability to transport and alter the full size distribution.

Nevertheless, it is quite difficult to quantify exactly the differences in the shape of the PSD at 1 km and the PSD near the surface. This is the reason why we choose to rely on the measured FENNEC-PSD at 1 km neglecting the sedimentation from this altitude down to the surface. However, following the reviewer's recommendation, we calculated a settling rate from the volume difference with height (dV/dz), derived from the "observed FENNEC-PSD" of freshly uplifted dust at height 1 and 1.5 km (Figure S2a from Ryder et al., 2013). Given that settling rate, we estimated with extrapolation, a new volume size distribution, called "FENNEC-PSD-0km", which corresponds to the surface (blue squares, Figure R1a). The blue solid line corresponds to the lognormal size distribution fitted to the blue squares, hereafter "fitted FENNEC-PSD-0km". Then, we calculated the new

$k_{factors}$ based on the volume size distribution "fitted FENNEC-PSD-0km". A comparison between the previously used $k_{factors}$ (based on the "fitted FENNEC-PSD", black line) and the new ones (based on the "fitted FENNEC-PSD-0km", blue line) is shown below in the Figure R1b: It is evident that the contribution of bin 5 is greater for the "fitted FENNEC-PSD-0km" than for the "fitted FENNEC-PSD" (at 1km), which is used in the paper. We use the new $k_{factors}$ to run an additional simulation CONTROL-nPSD. A comparison of the volume size distribution above an emission grid point (similar to Figure 5 in the manuscript) from CONTROL (blue line) and CONTROL-nPSD (orange line) runs is presented in Figure R2. According to the results we notice only a small improvement using the fitted FENNEC-PSD-0km. Despite the small improvement, the results suggest that the use of a coarser PSD has the tendency to improve the model PSD representation. Possible new measurements from near the sources, which reveal coarser PSDs near the ground, could be used in future studies.

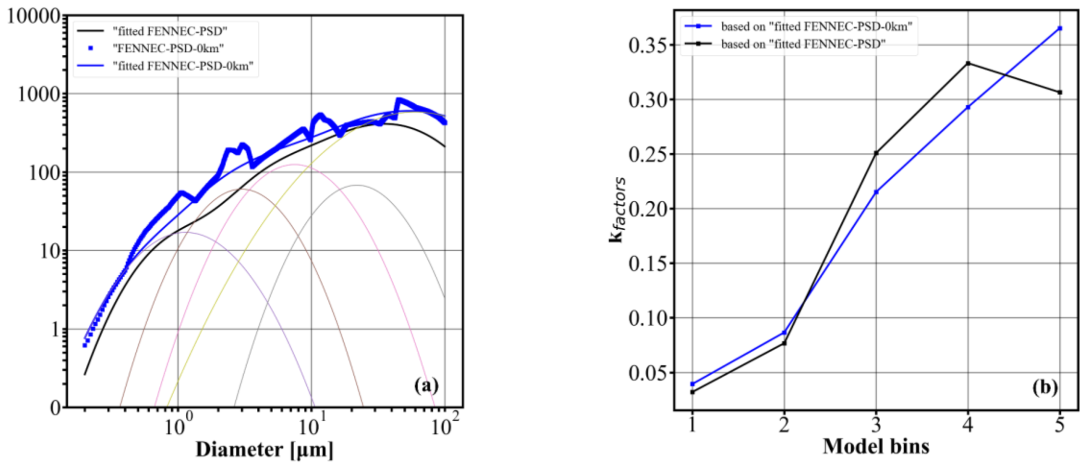


**Figure R1:** a) "fitted FENNEC-PSD" (black line), FENNEC-PSD-0km (blue squares) estimated with extrapolation, applying the same volume difference per meter as that which holds between the measurements at 1km and 1.5km , and the corresponding "fitted FENNEC-PSD-0km" (blue solid line).

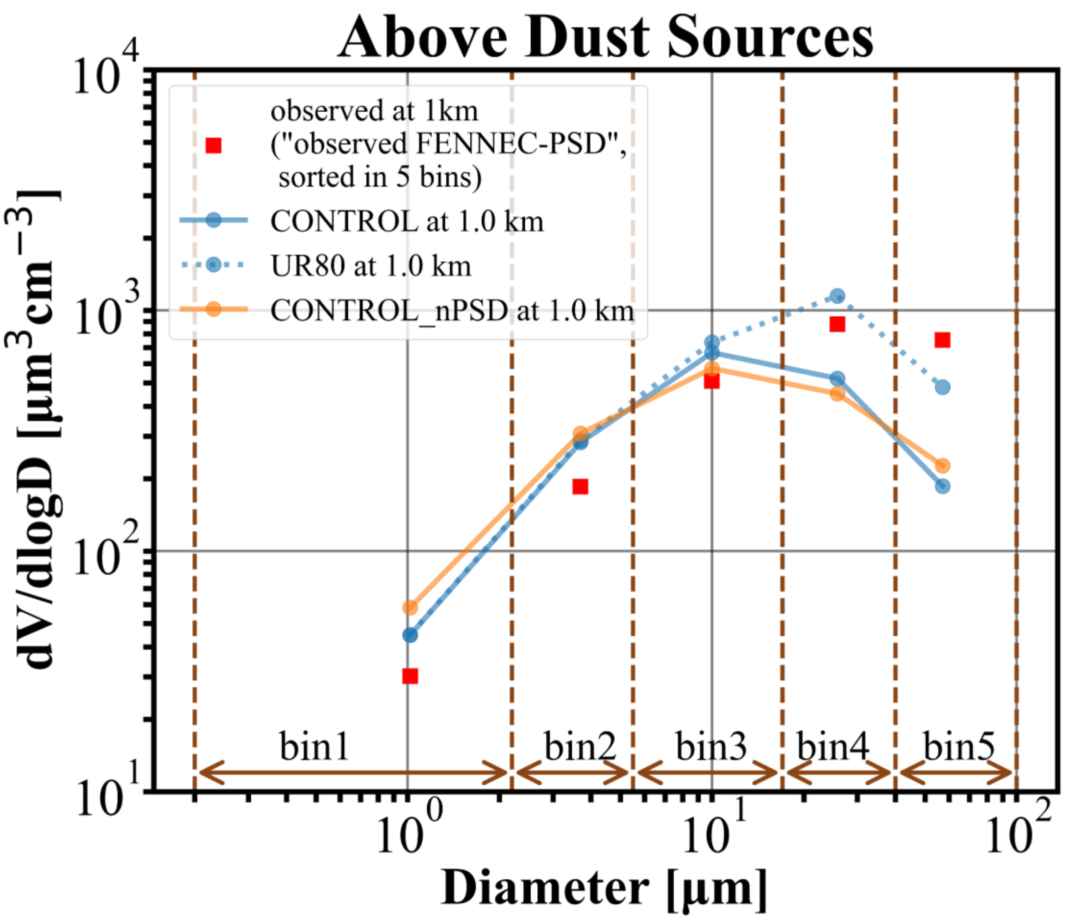


**Figure R2:** The "observed FENNEC-PSD" of freshly uplifted dust during FENNEC 2011 campaign (red squares), the model volume PSD above a source grid point from CONTROL run (blue line) and from CONTROL-nPSD run (orange line).

Based on our reply we included Fig R1 and Fig R2 in the Supplementary material (as Fig. S2 and Fig. S3, respectively) and added a related comment in the discussion of Fig. 5 of the revised manuscript, regarding the model underestimation for bin 4 and 5 above dust sources in lines 350-355, page 12:

*"Therefore, a model weakness is revealed at the very early phase of dust transport. Those differences can be attributed to an overestimation of their loss during uplift from the surface to 1 km, or to higher updrafts that remain unresolved in our numerical experiment. Another possible source of this underestimation could be the utilization of a not well-defined PSD shape constraining the distribution of emitted dust mass to the model transport size bins. A use of a PSD with higher contribution of coarse and giant dust particles could possibly*

*improve the representation of the coarse and giant particles aloft (Fig. S2 and S3) and can be assessed in future studies."*

**I understand that the sensitivity experiments on settling have been performed to mimic the effects of other processes. This is particularly applicable to effects of particle asphericity. However, the effects of other processes mentioned in the introduction, e.g. turbulence or vertical mixing in the Saharan Air Layer, are most likely much less homogeneous than settling and much more closely related to the meteorological conditions. I am not convinced that sensitivity experiments on the settling velocity are suitable to represent the effects of these processes. My recommendation is therefore to focus the manuscript on settling (which contains uncertainties as well, e.g. due to asphericity) and only discuss the other processes as possible additional contributors.**

We agree with the reviewer's concerns, thus we have revised the related parts of the manuscript according to reviewer's recommendation in Section 2.1.3 (see lines 244-254, page 9):

*"A series of additional sensitivity runs has been performed aiming to resemble possible mechanisms (misrepresented or even absent in the model) counteracting gravitational settling towards reducing the differences between the CONTROL run calculations and the in-situ observations (shown in Sect. 3.4). To be more specific, we gradually reduced (with an incremental step of 20%) the settling velocity by up to 80%, with the corresponding runs named as URx (x corresponds to the reduction in percentage terms). Under such theoretical conditions, it is expected that the giant dust particles will be suspended for longer periods and that they will be transported at larger distances than the current state-of-the-art models simulate, failing to reproduce what is observed in the real world. Based on these sensitivity experiments, we defined a constant (by percentage) relevant reduction of the particles' settling, which in its absolute value varies with size. Therefore, it is more similar to the effects that are related to aerodynamic forces due to the non-spherical shape and the orientation of the suspended dust particles (Ginoux, 2003b; Loth, 2008; Zastawny et al., 2012; Shao et al., 2017; Sanjeevi et al., 2018; Mallios et al., 2020)."*

**At several locations in the manuscript average PSDs or other quantities are discussed, but (some examples are mentioned below), but it was often not clear to me what averages those are**

**(temporal, spatial, weighted?). I might have missed it, but I suggest to check this and clearly state how the shown and discussed quantities have been calculated.**

We agree with the reviewer, and after also taking into account the other reviewers' comments, we have revised the manuscript providing more details regarding the modelled and observed PSDs in several parts of the revised manuscript.

In Section 2.1.1, we describe the methodology for the modification of the dust parameterization in WRF-L and we refer to the PSD data that we have used to do so, in line 141-148, page 5:

*"We rely on prescribed PSD for the emitted dust particles at the source based on the airborne in situ measurements acquired during the FENNEC campaign of 2011 (Ryder et al., 2013a). More specifically, for the freshly uplifted dust we use the mean PSD at the lowest available height (i.e., 1km) t, obtained by averaging profile measurements above the Sahara (Mauritania and Mali), hereafter called the "observed FENNEC-PSD", which is shown in Fig. 2(a) with red squares. Figure 2a shows also the "fitted FENNEC-PSD" (solid red line), which is the fit of the "observed FENNEC-PSD", using five lognormal modes (Table 4). In Sect. 2.2.1 more information is provided on the derivation of the mean "observed FENNEC-PSD", including also the description of the FENNEC 2011 campaign, the in-situ instrumentation used and the processing of the acquired data."*

We also modified the caption of Fig.2 which presents the data which are used for the parameterization, by providing more details in line 899-905, page 31 of the revised manuscript:

*"**Figure 2: Prescribed dust size distribution used in the WRF-L for the distribution of total dust mass to the transport model size bins: (a) "observed FENNEC-PSD" ($\mu m^3 cm^{-3}$) (red squares), and the respective "fitted FENNEC-PSD" (red solid line). The "observed FENNEC-PSD" corresponds to the PSD observations at 1km, obtained by averaging profile measured data of freshly uplifted dust cases, over 500m. The shaded areas indicate the model transport size bins in WRF-L. Error bars indicate the standard deviation of the observed values (b) The $k_{factors}$ of the transport size bins calculated based on "fitted FENNEC-PSD", provide the mass fraction of the emitted dust for each bin.**"*

We also modified Section 2.2.1, where we describe in a more detailed way the PSDs that we have used in this work, both for the modification of the dust parameterization and the evaluation of the model results. In the additional information, details regarding the instrumentations and the respective measurement uncertainties are included. The revised section is positioned in line 278-306, page 10-11:

*"During the FENNEC field campaign in 2011 (Ryder et al., 2013b, 2013a) and the AER-D field campaign in 2015 (Ryder et al., 2018, 2019), airborne in situ observations were collected with the FAAM BAE research aircraft.*

*In this study we use size distributions from the FENNEC field campaign, aquired during aircraft profiles over the Sahara (Mauritania and Mali), as described in Ryder et al. (2013a). We select size distributions from "freshly uplifted dust" cases, when dust particles are in the atmosphere for less than 12 h. Additionally, from these profiles we use data from the lowest available altitude, centered at 1km, covering altitudes between 0.75 to 1.25km. The derived PSD is depicted in Fig.2(a), hereafter referred to as the "observed FENNEC-PSD". Error bars in Fig.2(a) indicate the standard deviation of the observed values across the profiles and altitudes we used. The instrumentation for those measurements was the Passive Cavity Aerosol Spectrometer Probe (PCASP, 0.13-3.5 μm), the Cloud Droplet Probe (CDP, 2.9-44.6 μm), using light scattering measurements and assuming a refractive index (RI) of 1.53-0.001i (which is constant with particle size), spherical shape for the particles, and using Mie calculations to convert from optical to geometric diameter, as well as the Cloud Imaging Probe (CIP15, 37.5-300 μm)). The instruments and data processing are described in Ryder et al. (2013a). The midpoint size bin diameters do not overlap, though there is some overlap in bin edges between the instruments. A fit on the observations is provided in Figure 2a (the "fitted FENNEC-PSD" with solid red line), which is used in the parameterization of the emitted dust, as described in Section 2.1.1, to modify the GOCART-AFWA dust scheme in WRF.*

*We also use PSD observations during horizontal flight legs at a constant height (referred either as RUNs or flight segments) over the Atlantic Ocean during AER-D. We use measurements taken with PCASP (D =0.12-3.02 μm) for fine dust particles. For the coarse and giant mode of dust we used measurements from CDP (D=3.4-20 μm, although CDP measurements availability extends up to 95.5 μm as it is explained below) and the two-dimension Stereo probe (2DS, D = 10–100 μm -although the instrument measures up to 1280 μm few particles larger than 100μm were detected). For the light scattering techniques of PCASP and CDP, a RI = 1.53-0.001i is assumed for the conversion of the optical to geometric diameter (as in FENNEC 2011 campaign). CDP observations extend up to the size of 95.5 μm, thus data from CDP and 2DS partly overlap in their size range. Since 2DS observations are more reliable in the overlapping size range, we used the CDP observations for particles with sizes up to 20 μm. Also, 2DS-XY observations are preferred over the 2DS-CC, since they better represent the non-spherical particles. A more detailed description of the in-situ instruments and the corresponding processing of the data acquired during the AER-D campaign is included in Ryder et al., (2018). The error bars represent the total (random and systematic) measurement error due to the counting error, the discretization error, the uncertainties in the sample area and the uncertainties in the bin size due to Mie singularites (Ryder et al., 2018). All PSD measurements are at ambient atmospheric conditions. The locations of the flights of AER-D used in this study are depicted in Fig.3."*

In Section 3.4 of the revised document, we provided more information about the collocation of the model data to the AER-D flights in line 375-383, page 13:

*"The modelled PSDs are collocated in space and time with the measurements of each flight segment. For each flight segment, we extract the modeled PSD by interpolating the dust field to the specific altitude of the flight RUN. Additionally, we average the dust field of the nearest grid cell to each coordinate pair along the flight segment track, and the eight neighbouring grid cells of the same altitude. The coordinates of the flight leg track are depicted with orange dots and the collocated grid points used for deriving the modelled PSD (at the specific height of each flight leg) with blue dots. In the time dimension, we average the two hourly model outputs that contain the times of the measurement. In case that the time of measurement coincides with the exact hourly output, the model output on that hour along with the outputs prior and after that are averaged. The error bars in the model PSDs indicate the standard deviation of the collocated grid points averaging in space and time."*

Additionally, we revised Fig.3, describing in more detail, the AER-D campaigns flight segments that we have used in this work, their locations and the respective collocated model grid points that we used for the model-observation comparison in Fig.8 and Fig S4. The revised Fig. 3 is inserted in lines 896-900, page 32 of the revised manuscript:

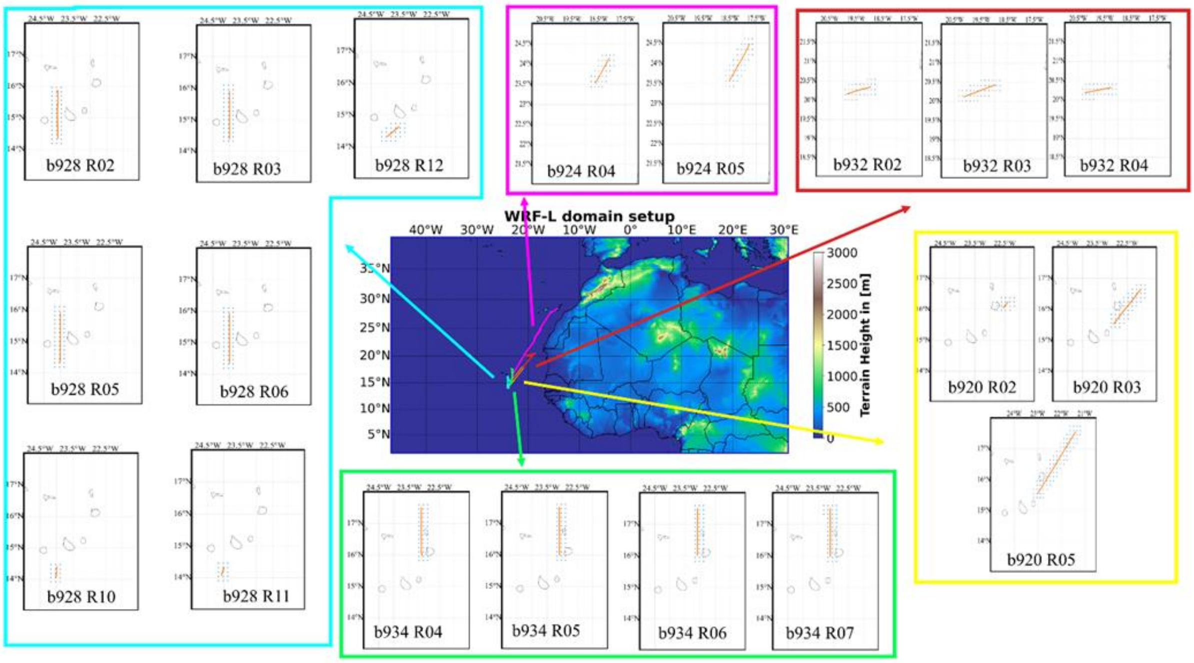


***Figure 3: Domain and topography map of the WRF-L model simulations, with a horizontal grid spacing of 15km, and 70 vertical levels. The tracks of the AER-D flights, used in this study (b920, b924, b928, b932 and b934), are depicted in the central plot with different colours. The aircraft tracks of each flight RUN are also***

***depicted with the orange dots in the surrounding maps. The blue dots correspond to the collocated model grid points."***

In Section 3.3 we discuss Fig.6 which shows the mean modelled dust load temporarily averaged of the CONTROL experiment, averaged over the period of the simulation (5/8/15- 25/8/15) after neglecting the period that is used as the simulation spin-up. We modified the related part in page 12, lines 361-362 to avoid any misunderstanding:

*"In Fig. 6, the spatial patterns of the columnar dust concentrations are depicted, averaged over the period of 5/8/15- 25/8/15, for the total mass as well as for each one of the five size bins simulated with the CONTROL run."*

We also revised Section 3.4, where we discuss Fig.8 (Fig.9 in the original manuscript). In Fig.8a we present the mean modelled and observed PSDs during the AER-D within all flight segments of Fig.3 (including the neighbouring points). Since the location of each flight segment and the respective time of measurement is different (the exact locations are presented in the revised Fig.3 - line XX, page XX - and the exact times of measurement in Fig.S4), the averaging is made both in time and space and the error bars indicate the standard deviation. The revised related part is inserted in line 13, page 394-396 of the revised document:

*"The overall comparison of the observed and modelled average PSDs is presented in Fig 8. We consider that all the in-situ airborne measurements and the WRF-L numerical outputs satisfy the defined spatiotemporal collocation criteria. Error bars indicate the corresponding standard deviation."*

In Fig. 8b (Figure 9b in the original manuscript), we present an alternative comparison between observations and model volume concentrations, for the selected AER-D samples. First, we calculated the total dust volume concentration by integrating the modelled and observed PSD of each flight segment. Then, we find the relative difference of the total volume concentration with respect to observations for each flight segment expressed in percentage. That relative difference of the total volume concentration is denoted in Fig 9b (using different marker styles) with respect to the specific altitude that the flight segment occurred. The dashed coloured vertical lines show the corresponding differences (in percentage) spanning from near-surface up to ~4.2 km. The different colours correspond to the different numerical experiments. These differences are calculated as the average of the relative differences of each flight segment. The revised related part is inserted in lines 403-407, page 14 of the revised document:

*"More specifically, we calculate for each model experiment (denoted with different colour), the relative differences (expressed in percentage) of the total dust volume concentration with respect to the in-situ measurements. In addition, the corresponding differences (in percentage terms) that are representative for the altitudes spanning from near-surface up to ~4.2 km are denoted with the vertical coloured dashed thick lines (WRF-L experiments). Those differences are derived by averaging the relative differences of each flight segment."*

**L 14 Why is there a limit of dust particle sizes (0.2 < D < 100 um), in particular in the context of observations?**

We agree with the reviewer that such a statement about the size limits of the observed dust particles here is wrong. Since there is a detailed reference in the Introduction about the sizes of the observed dust particles in the atmosphere, we have omitted the content of the parenthesis from the abstract of the original manuscript. Nevertheless, we should note that both Fennec and AER-D field campaigns provided observations of particles much larger than 100 μm, but AER-D was curtained at 100 microns because few larger particles were detected, resulting in instrument noise at these sizes. The same is true for the Fennec campaign, for particles larger than 500 microns. Based on our reply we have modified the revised manuscript in lines 13-16, page 1:

*"Dust particles larger than 20 μm in diameter have been regularly observed to remain airborne during long-range transport. In this work, we modify the parameterization of the mineral dust cycle in the GOCART-AFWA dust scheme of WRFV4.2.1, to include also such coarse and giant particles, and we further discuss the underlying misrepresented physical mechanisms which hamper the model in reproducing adequately the transport of the coarse and giant mineral particles."*

**L 15 The formulation "extend the parameterization of the mineral dust cycle" is not suitable. The parameterization of the mineral dust cycle (emission, transport [which includes itself several parameterizations], and deposition [again more than one parameterization]) was not extended, but some aspects of it were modified. The same applies for "our parameterization" (L 17).**

We agree with the reviewer that the choice of the verb "extend" is not suitable for describing our methodology, thus we have modified the related part in the revised manuscript in lines 14-16, page 1:

"*In this work, we modify the parameterization of the mineral dust cycle in the GOCART-AFWA dust scheme of WRFV4.2.1, to include also such coarse and giant particles, and we further discuss the underlying misrepresented physical mechanisms which hamper the model in reproducing adequately the transport of the coarse and giant mineral particles.* "

**L 21 - 22 Those additional processes have been proposed in the past, hence this statement is inaccurate. I suggest revising it and stating (after mentioning the sensitivity experiments) that those processes are discussed as candidates to cause such a reduced settling.**

We agree with the reviewer, thus we have revised the related parts of the revised manuscript in the abstract according to the reviewer's suggestion in lines 20-23, page 1

*"The results show that the modelled lifetimes of the coarser particles are shorter than those observed. Several sensitivity runs are performed by reducing artificially the particles' settling velocities in order to compensate underrepresented mechanisms, such as the non-spherical aerodynamics, in the relevant parameterization schemes."*

**L 24 in the range**

Done

**L 25 UR60 has not yet been introduced**

Done

**L 30 Important to mention that dust only ranks first/second by mass.**

Here we state that dust aerosol ranks first in mass burden and second in emission. This is based on median values from all models that participated in AEROCOM Phase III. Those results, which are close to the results of AEROCOM Phase I (*Huneeus et al., 2011;* Textor et al., 2006), are depicted in Table 3 of Gliβ et al., (2021). Based on our answer modified the lines 32-33, page 2 of the revised manuscript

*"Dust is the most prominent contributor to the global aerosol burden, in terms of dry mass, and it ranks second in aerosol emissions (Glißet al., 2021; Huneeus et al., 2011; Textor et al., 2006)."*

**L 32 Dust can be windblown, but I believe the emissions cannot.**

Absolutely. Corrected.

**L 34 Aren't all regions "spatially limited"? Perhaps use "Spatially more limited".**

Thank you. Corrected.

**L 41 after their wet and dry deposition**

Done

**L 46 I propose "cloud microphysical processes and their evolution" [omit the dissolution part] as I believe the processes do not stop.**

Absolutely. Corrected.

**L 51 Please give a reference for this diameter range. The lower limit seems relatively large to me.**

We would like to thank the reviewer for pointing this out. Of course, there are smaller dust particles in the atmosphere than 0.2 μm. Our statement is erroneously driven by the range of the model sizes. Thus, we have revised the manuscript by removing that statement.

**L 65-66 gravitational settling**

Done

**L 69 of all cases**

Done

**L 70 Please give a (spatial) reference for "larger distances"**

In Weinzierl et al., 2017a authors estimated that particles with diameters 10-30 μm occur approximately at 2000km further from their sources, than it is expected, based on Stoke's law, under no shear conditions and assuming the initial height of the observations taken. Based on that, we added the spatial reference for larger distances in the manuscript revising the original manuscript in line 72, page 3:

*"Dust particles with diameters of 10 to 30 μm were detected during the SALTRACE campaign in Barbados (Weinzierl et al., 2017a), revealing that they were suspended far away from their sources at about 2000 km more than what would be expected from the Stokes' theory (Weinzierl et al., 2017a)"*

**L 71 Stokes' theory is on settling, not on gravity.**

Absolutely. Corrected.

**L 112 The modified model version considers dust up to 100 microns, but airborne dust particles can also be larger, hence "the entire size range" is exaggerated.**

Absolutely. We rephrase the statement in line 116, page 4 of the revised manuscript.

*"in* ***step 2****, we define five size ranges (five model size bins) for the transported PSD covering dust particle sizes spanning from 0.2 μm to 100 μm (Sect. 2.1.1);"*

**L 131 Please add [in the default GOCART-AFWA] dust emission scheme [of (in) WRF]**

Done.

**L 152 Please introduce variables directly to Eqs. 3 and 4.**

Done.

**L 160 The Cunningham correction is missing in Eq. 5**

We would like to thank the reviewer for noticing these errors. In the revised manuscript, we have corrected equations and based RC2 reviewer suggestions we reconstruct the Section 2.1.2 to make it less lengthy. In the revised text Cunningham correction is introduced in Eq.4 and is given by Eq.5. The revised Section 2.1.3 (see lines 156-214, pages 6-8) is shown below:

*"In the GOCART-AFWA dust scheme of WRF, the forces acting on a dust particle moving along the vertical direction are the gravitational force $F_g$ and the aerodynamic drag force $F_{drag}$, which are mathematically expressed in Eq.3 and Eq.4, respectively.*

$$F_g = \rho_p \cdot V_p \cdot g, \quad (3)$$

$$F_{drag} = \frac{1}{2} \cdot \frac{C_D}{C_{cun}} \cdot A_p \cdot \rho_{air} \cdot u_{term}^2, \quad (4)$$

*Where $\rho_p$ stands for particle density in kgm$^{-3}$, $g$ corresponds to the gravitational acceleration in ms$^{-2}$, $V_p = \frac{1}{6} \cdot \pi \cdot D_{eff}^3$ is the particle volume in m$^3$ and $A_p = \frac{\pi}{4} \cdot D_{eff}^2$, is the particle's projected area normal to the flow in m$^2$, $\rho_{air}$ is the air density in kgm$^{-3}$. and $D_{eff}$ represents the particles' diameter in m for each model size bin (assuming spherical particles, as defined in Sect. 2.1.1). $C_D$ is the aerodynamic drag coefficient (unit less) and $C_{cun}$ is the slip correction to account for slip boundary conditions (Davies, 1945) and it is expressed as a function of the air mean free path ($\lambda$, in meters) (Eq. 5):*

$$C_{cun} = C_{cun}(\lambda) = 1.0 + \frac{2 \cdot \lambda}{D_{eff}} [1.257 + 0.4 \cdot e^{\frac{-1.1 \cdot D_{eff}}{2 \cdot \lambda}}], \quad (5)$$

*The constant velocity that a particle builds up falling vertically within the Earth's atmosphere, is defined as the terminal settling velocity* $u_{term}$*, and it can be estimated by solving the 1-D equation of motion at the steady state limit, where net force is assumed to be equal to zero:*

$$\rho_p \cdot V_p \cdot g = \frac{1}{2} \cdot \frac{C_D}{C_{cun}} \cdot A_p \cdot \rho_{air} \cdot u_{term}^2, \qquad (6)$$

*In the default GOCART-AFWA dust scheme the drag coefficient is given by Stokes' Law and is defined as:*

$$C_D = \frac{12}{Re}, \qquad (7)$$

*Where* $Re$ *is the Reynold's number (unit less) given by the following equation as a function of the particle volume equivalent effective diameter* $D_{eff}$*:*

$$Re = \frac{\rho_{air} \cdot u_{term} \cdot D_{eff}}{2 \cdot \mu}, \qquad (8)$$

*Where* $\mu$ *is the air dynamic viscosity in* $\frac{kg}{m \cdot s}$ *defined as a function of air temperature* $T$ *in* $K$ *by the following equation (Hilsenrath, 1955; United States Committee on Extension to the Standard Atmosphere., 1976):*

$$\mu = \frac{\beta \cdot T^{\frac{3}{2}}}{T+S}, \qquad (9)$$

*where* $S$ *is the Sutherland constant which equal to* $110.4\ K$ *and* $\beta$ *is a constant which equals to* $1.458 \cdot 10^{-6}\ kg \cdot m^{-1} \cdot s^{-1} \cdot K^{-1/2}$ *.*

*and the air mean free path is expressed as:*

$$\lambda = \frac{1.1 \cdot 10^{-3} \cdot \sqrt{T}}{P} \qquad (10)$$

*Where* $T$ *is the air temperature in* $K$ *and* $P$ *the air pressure in* $hPa$*.*

*The slip-corrected drag coefficient of the Stokes' Law (*$\frac{12}{Re \cdot C_{cun}}$*) is valid only for Re <<1, thus it is not representative for particles with* $D_{eff}$ *larger than ~10 μm. Therefore, an adaptation of the drag coefficient is needed in order to be valid for higher Re values (i.e., 0<Re<16), since in our work dust particles with diameters larger than 20 μm are considered. To realize, we use the drag coefficient* $C'_D$ *(Eq. 11), proposed by Clift and Gauvin, (1971):*

$$C'_D = \frac{12}{Re} \cdot (1 + 0.2415 \cdot Re^{0.687}) + \frac{0.42}{1+\frac{19019}{Re^{1.16}}},\ for\ \ Re < 10^5$$

*(11)*

*Mallios et al., (2020) used the same $C'_D$ as a reference for the development of a drag coefficient for prolate ellipsoids, as more suitable for $Re < 10^5$. The departures between the drag coefficients given by Stokes and Clift and Gauvin (1971) become more evident for increasing particles' sizes. More specifically, the drag coefficient given by Clift and Gauvin (1971) can be up to 2 times higher than those of the Stokes' Law for coarse and giant particles (Fig. S1).*

*In the default WRF code the slip correction is applied unconditionally for all the Re values, probably without affecting the solution significantly due to the small particle sizes ($D_{eff} < 20\ \mu m$). However, in our work required a condition is required for applying the slip correction only in the Stokes' regime (e.g. Re < 0.1, Mallios et. al, 2020). Hence, we apply the bisection method to calculate the terminal velocity for each model size bin using the revised drag coefficient and, at first, ignoring the slip correction. When the solution lies in the Stokes' regime (e.g. Re < 0.1), we recalculate the settling velocity using the corrected drag coefficient $C'_{D,slip} = \frac{C'_D}{C'_{cun}}$, where $C'_{cun} = C_{cun}(\lambda')$ with $\lambda'$ the mean free path obtained by (Jennings, 1988):*

$$\lambda' = \sqrt{\frac{\pi}{8}} \cdot \frac{\frac{\mu}{0.4987445}}{\sqrt{P\rho_{air}}},$$

*(12)"*

**L 172/176 I know the drag coefficient equation for the Stokes regime as C_D = 24 / Re with Re = U D / nu with nu = mu / rho. Is there any reason I am missing why the formulation shown here is different and contains the factor 2 in Re rather than C_D? (The result is the same.)**

We can understand the reviewer's confusion. All equations are written in such a way to be a function of particle diameter.

**L 178/192 The Kelvin scale has no degree symbol.**

Thank you for pointing this out. It is corrected.

**L 182 I don't think Equation 7 is meant here. Equation 4 maybe?**

Thank you. It is corrected.

**L 184 delete become**

Done.

**L 193 Eq. 13?**

Thank you. Corrected.

**L 200 remove parenthesis around first reference**

Done.

**L 208 Re < 1?**

The limit Re<0.1 is correct. There is a more detailed explanation for the reasons behind that on Mallios et. al 2020. However, we have revised the revised document to be clearer in lines 207-214, pages 7-8:

"In the default WRF code the slip correction is applied unconditionally for all the Re values, probably without affecting the solution significantly due to the small particle sizes ($D_{eff} < 20$ μm). However, in our work required a condition is required for applying the slip correction only in the Stokes' regime (e.g. Re < 0.1, Mallios et. al, 2020). Hence, we apply the bisection method to calculate the terminal velocity for each model size bin using the revised drag coefficient and, at first, ignoring the slip correction. When the solution lies in the Stokes' regime (e.g. Re < 0.1), we recalculate the settling velocity using the corrected drag coefficient $C'_{D,slip}=\frac{C'_D}{C'_{cun}}$, where $C'_{cun} = C_{cun}(\lambda')$ with $\lambda'$ the mean free path obtained by (Jennings, 1988):

$$\lambda' = \sqrt{\frac{\pi}{8}} \cdot \frac{\frac{\mu}{0.4987445}}{\sqrt{P\rho_{air}}}, \quad (12)$$"

**L 218 Why did the authors choose to include so much ocean in their domain while omitting east N African dust sources? This seems not an ideal choice to me.**

We made the choice to use this domain because the airborne in-situ observations of the PSD have been acquired in the surrounding area of Cape Verde, so we decided to have this location very close to the centre of our computational domain. Moreover, the main sources affecting this area of interest during the boreal summer (August 2015), are encompassed within the simulation domain. Dust sources in East Africa have negligible effect on dust concentrations over Cape Verde, so we decided to omit them. Ideally the model domain can be increased towards the East and the North, but the computational cost is large compared to any small anticipated benefits.

**L 225-226 The authors state that "scaling of the dust source strength is chosen to best match the modeled DOD with the AERONET measurements". I would like to know more about this. What scaling do you refer to? Is this a universal scaling/tuning factor or a map scaling? Did you modify the Ginoux/GOCART erodibility function typically used in WRF or is a different scaling used? How has the modeled dust been compared with the observations to infer any kind of scaling? Please give more detail as this is an important aspect of the modeled dust fields.**

We adjust the empirical constant in the equation of horizontal saltation fluxes emission (Cmb in Eq.10 in LeGrand et al., 2019) in order to have the best statistical agreement between AERONET filtered AOD and model DOD. Based on our reply we have include additional information in line 229-235, page 8:

"We scale the dust source strength, by tuning the empirical proportionality constant in the horizontal saltation flux equation (in eq. 10 in LeGrand et al., (2019)) in order to obtain the best match between the modeled DOD and the AERONET AOD (RMSE=0.34, bias=-0.07) acquired at 8 desert stations: Banizoumbou, Dakar, El_Farafra, Medenine- IRA, Oujda, Tizi_Ouzou, Tunis_Carthage, Ben_Salem). Note that we take into account only AERONET records when AODs are higher than 0.2 (Version 3.0, Level 1.5, Giles et al., 2019; Sinyuk et al., 2020) and the Angstrom exponent is lower than 0.75. The tuning constant is equal to 3 and is applied throughout the model domain."

**L 228 A minimum DOD of 0.75 seems very high to me, even close to dust sources.**

We would like to thank the reviewer for noticing that. Actually, the filtering of AERONET dust AOD-like is made by defining a lower (0.2) and an upper (0.75) threshold on AOD and Angstrom, respectively. The necessary clarifications have been incorporated in the revised manuscript in line 232 , page 8:

"Note that we take into account only AERONET records when AODs are higher than 0.2 (Version 3.0, Level 1.5, Giles et al., 2019; Sinyuk et al., 2020) and the Angstrom exponent is lower than 0.75."

**L 233 by up to 80 % with a step size…**

Done.

**L 234 "sensitivity experiment" instead of "artificial tuning"**

Done.

**L 235 Please revise "falling into the atmosphere"**

We agree with the reviewer that this statement needs revision, thus we have modified the original manuscript, based on this comment and the next one in lines 244, page 9 of the revised document:

*"A series of additional sensitivity runs has been performed aiming to resemble possible mechanisms (misrepresented or even absent in the model) counteracting gravitational settling towards reducing the differences between the CONTROL run calculations and the in-situ observations (shown in Sect. 3.4). To be more specific, we gradually reduced (with an incremental step of 20%) the settling velocity by up to 80%, with the corresponding runs named as URx (x corresponds to the reduction in percentage terms). Under such theoretical conditions, it is expected that the giant dust particles will be suspended for longer periods and that they will be transported at larger distances than the current state-of-the-art models simulate, failing to reproduce what is observed in the real world. Based on these sensitivity experiments, we defined a constant (by percentage) relevant reduction of the particles' settling, which in its absolute value varies with size. Therefore, it is more similar to the effects that are related to aerodynamic forces due to the non-spherical shape and the orientation of the suspended dust particles (Ginoux, 2003b; Loth, 2008; Zastawny et al., 2012; Shao et al., 2017; Sanjeevi et al., 2018; Mallios et al., 2020)."*

**L 236 "all real forces" is exaggeration. Gravitation and drag forces are real and**

Absolutely. We revised the related statement in line 250, page 9 of the revised manuscript:

*"Based on these sensitivity experiments, we defined a constant (by percentage) relevant reduction of the particles' settling, which in its absolute value varies with size. Therefore, it is more similar to the effects that are related to aerodynamic forces due to the non-spherical shape and the orientation of the suspended dust particles (Ginoux, 2003b; Loth, 2008; Zastawny et al., 2012; Shao et al., 2017; Sanjeevi et al., 2018; Mallios et al., 2020)."*

**L 240 What “fine resolution” are your referring to here? I would not consider 15 km a particularly fine resolution. Also, Table 3 does not contain any experiments on resolution (L 248).**

The resolution applied here is adequate for the scale of phenomena we want to study. By "fine" resolution we wanted to denote that we have a finer resolution than global datasets (e.g. 0.5deg GFS) which will fail to reproduce the appropriate weather fields. However the reviewer is correct that this can be misleading so we made changes to the text to be clearer in line 235, page 8.

*“The resolution applied in this study (15km grid spacing) is adequate for the scale of phenomena we want to study, improves the representation of topography and increases the accuracy of the reproduced weather and dust fields, compared to coarser resolution, such as used in global datasets (e.g. 0.5 deg GFS) (Cowie et al., 2015; Basart et al., 2016; Roberts et al., 2017; Solomos et al., 2018).”*

**L 243 Dunes are no meteorological condition.**

Absolutely. Based on other comments we have removed this part.

**L 270 The explanation is hard to understand, please revise it if possible. How did you handle missing values in the observations for the model comparison?**

Obviously, the description needs improvement. In the model, the DOD is computed in each grid model box and its instantaneous value is provided every one hour. The DOD value from Aqua satellite is acquired from the ModIs Dust AeroSol (MIDAS) DOD product, based on the following spatiotemporal collocation procedure: First, we reproject the model DODs on an equal lat-long grid at 0.4° x 0.4° spatial spacing. We should note that the model DOD field has no spatial gaps and is provided instantaneously for every hour. The MIDAS DOD is available in swath level (5-minute segments, viewing width of 2330 km) along the MODIS-Aqua polar orbit. Then, the two closest WRF outputs to the Aqua satellite overpass time are used to calculate a weighted-average WRF-DOD, by taking into account the temporal departure between forecast and overpass times, only for the WRF grid cell that coincides with the observations. Please note that we have removed the corresponding part related to b920 flight, based on RC3 comment. Please note that based on next comment suggestion about the discussion of Fig.7 of the original manuscript, the related part has been removed.

**L 288 I suggest mentioning here again how the FENNEC PSD has been used. This will be as brief as mentioning that it is explained elsewhere (you can keep the reference toy Sec. 2.1.1).**

We agree with the reviewer's and other reviewers' suggestions and we have revised the whole 2.2.1 accordingly (see lines 278-306, pages 10-11):

*"During the FENNEC field campaign in 2011 (Ryder et al., 2013b, 2013a) and the AER-D field campaign in 2015 (Ryder et al., 2018, 2019), airborne in situ observations were collected with the FAAM BAE research aircraft.*

*In this study we use size distributions from the FENNEC field campaign, aquired during aircraft profiles over the Sahara (Mauritania and Mali), as described in Ryder et al. (2013a). We select size distributions from "freshly uplifted dust" cases, when dust particles are in the atmosphere for less than 12 h. Additionally, from these profiles we use data from the lowest available altitude, centered at 1km, covering altitudes between 0.75 to 1.25km. The derived PSD is depicted in Fig.2(a), hereafter referred to as the "observed FENNEC-PSD". Error bars in Fig.2(a) indicate the standard deviation of the observed values across the profiles and altitudes we used. The instrumentation for those measurements was the Passive Cavity Aerosol Spectrometer Probe (PCASP, 0.13-3.5 μm), the Cloud Droplet Probe (CDP, 2.9-44.6 μm), using light scattering measurements and assuming a refractive index (RI) of 1.53-0.001i (which is constant with particle size), spherical shape for the particles, and using Mie calculations to convert from optical to geometric diameter, as well as the Cloud Imaging Probe (CIP15, 37.5-300 μm)). The instruments and data processing are described in Ryder et al. (2013a). The midpoint size bin diameters do not overlap, though there is some overlap in bin edges between the instruments. A fit on the observations is provided in Figure 2a (the "fitted FENNEC-PSD" with solid red line), which is used in the parameterization of the emitted dust, as described in Section 2.1.1, to modify the GOCART-AFWA dust scheme in WRF.*

*We also use PSD observations during horizontal flight legs at a constant height (referred either as RUNs or flight segments) over the Atlantic Ocean during AER-D. We use measurements taken with PCASP (D =0.12-3.02 μm) for fine dust particles. For the coarse and giant mode of dust we used measurements from CDP (D=3.4-20 μm, although CDP measurements availability extends up to 95.5 μm as it is explained below) and the two-dimension Stereo probe (2DS, D = 10–100 μm -although the instrument measures up to 1280 μm few particles* *larger than 100μm were detected). For the light scattering techniques of PCASP and CDP, a RI = 1.53-0.001i is assumed for the conversion of the optical to geometric diameter (as in FENNEC 2011 campaign). CDP observations extend up to the size of 95.5 μm, thus data from CDP and 2DS partly overlap in their size range. Since 2DS observations are more reliable in the overlapping size range, we used the CDP observations for particles with sizes up to 20 μm. Also, 2DS-XY observations are preferred over the 2DS-CC, since they better represent the non-spherical particles. A more detailed description of the in-situ instruments and the corresponding processing of the data acquired during the AER-D campaign is included in Ryder et al., (2018). The error bars represent the total (random and systematic) measurement error due to the counting error, the discretization error, the uncertainties in the sample area and the uncertainties in the bin size due to Mie singularites (Ryder et al., 2018). All PSD measurements are at ambient atmospheric conditions. The locations of the flights of AER-D used in this study are depicted in Fig.3."*

**L 338/Fig. 5 Are the modelled PSDs for a particular time step or averaged?**

It is at the hourly model output at 15 UTC, which contains the model values for the corresponding time step. The information is included in lines 334-336, page 12 of the revised manuscript:

*"In Fig. 5 we present how the PSD varies with height above an emission point (latitude=24.9° and longitude=9.2°) in Mali, on 11/08/2015 at 14UTC. The model PSDs are only from that grid model box interpolated at 1, 2, and 3 km height and for the particular timestep (11/08/2015 at 14UTC) ."*

**L 360 I suggest showing deposition rates for bin 5 to see whether all particles have settled already over land.**

We have added in Fig. 6g a map for the time-averaged (from 5-25/8/2015) gravitational deposition rate of particles in bin 5. The map shows that the major mass of particles of size 5 is deposited not further than the African coasts. Almost all dust is deposited not further than the parallel of 20° W. The revise Fig 6 is inserted in lines 923-926, page 35 of the revised manuscript:

"

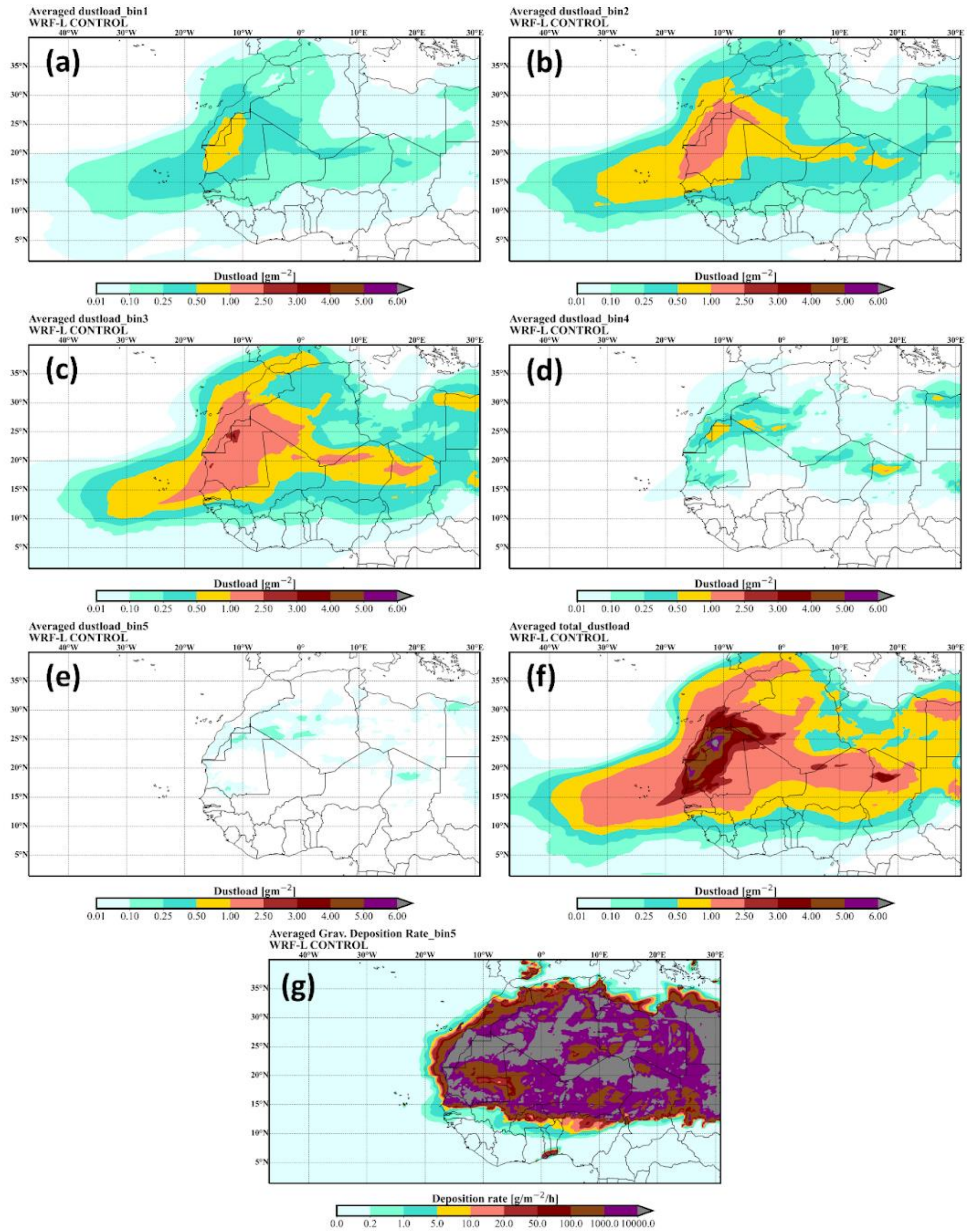


***Figure 6: The dust load provided by the model, averaged for the whole simulation period, for (a) bin 1, (b) bin 2, (c) bin 3, (d) bin 4, (e) bin 5, and (f) the whole range of the PSD. The dust load is in g/m2. (g) The gravitational deposition rate for bin 5.***

"

**L 363 – 375 The discussion about Flight b920 in the context of Fig. 7 is a bit confusing as Fig. 7 does not contain the PSD measured during the flight (but only the displaced dust plume). Why don't you show the PSD from b920 to provide a basis for the discussion?**

We agree with the reviewer that the discussion about flight b920 is a bit confusing, thus we excluded it for the manuscript.

**L 393 The relative difference shown in Fig. 9b does not seem to vary systematically with height for bin 5. Shouldn't this be expected?**

We would like to clarify that Figure 8b (Figure 9b in the original manuscript) shows the relative difference of the Total Volume concentration (sum of the concentration for the five model bins) which is contained in the PSD of each flight segment (different markers) versus the altitude of each flight segment. With different colours are the results from the different sensitivity tests and not for the different model size bins.

**L 397 What kind of average is the "mean extinction coefficient"?**

The LIVAS mean extinction coefficient is obtained by averaging all the LIVAS profiles per CALIPSO nighttime overpasses between 25.5$^o$W to 12.5$^o$E and 11.5$^o$N to 34.5$^o$N.

For the same overpasses, we obtained the model profiles collocated as described in Section 2.1.4. We thank the reviewer for noticing that the description needs improvements, so we revise the document accordingly in page 14 and lines 416-425 (of the revised document):

*"Figure 9(a) shows the profile of the mean extinction coefficient at 532 nm, provided by the LIVAS pure-dust product (black line), and the profile of the mean extinction coefficients at 550 nm, provided by the CONTROL, UR20, UR40, UR60, and UR80 experiments. The orange area indicates the standard deviation of the LIVAS profiles. Figure9(b) depicts the mean absolute model bias with respect to LIVAS profiles for the different simulations and the vertical dashed lines show the corresponding bias averaged over different altitudes. The mean LIVAS profile is provided by averaging the night-time profiles over the region bounded by between 25.5°W to 12.5°E and 11.5°N to 35.5°N and from dates spanning from 5 to 25 August 2015. This area includes the main dust sources that affected the vicinity of Cape Verde (Ryder et al., 2018) and the region of the dust outflow over the Ocean, as well. The nightime profiles excel in accuracy over the daytime ones, due to the lower signal-to-noise ratio (SNR) during the night. The model profiles are collocated in space and time with the LIVAS profiles, as described in Sect. 2.1.4 and the model extinction coefficient is provided with the Eq.13."*

**L 399-400 It has been discussed before how a few dust plumes were displaced, hence I do not agree with this general affirmation of simulation quality.**

We agree with the reviewer that there are departures in the vertical distribution of dust, thus we remove the affirmation.

**L 402 How can these mean (?) profiles be related to the night-time boundary layer? Was any more detailed analysis performed?**

In the framework of the present study, we implement LIVAS (LIdar climatology of Vertical Aerosol Structure for space-based lidar simulation studies), a 3-D multi-wavelength global aerosol and cloud optical database developed in the framework of the European Space Agency (ESA) activities, towards providing support for future satellite-based lidar missions (Amiridis et al, 2015). The LIVAS database provides vertical profiles of aerosol optical properties, including among others L2 QA profiles of extinction coefficient at 532 nm, not only for the total aerosol load, but also for the pure-dust component (Amiridis et al., 2013; Marinou et al., 2017; Proestakis et al., 2018), through implementation of an EARLINET (Pappalardo et al., 2014) established methodology (Tesche et al., 2009). However, the original ESA-LIVAS database which is implemented to address the scientific questions of the present study, does not provide the PBL information. Moreover, although MERRA-2 is extensively implemented in the framework of CALIOP algorithms, CALIPSO L2 Aerosol/Cloud Profiles 5 km do not provide information on PBL at per-CALIPSO orbital level. Thus, neither CALIPSO nor the ESA-LIVAS database, the observational lidar-based satellite products and datasets extensively analysed and implemented as references towards the evaluation of the model-based outputs in the framework of the study, provide input on the PBL, to be used here. Estimation is based on the shape of the climatological vertical structure of the mean extinction coefficient profile at 532 nm, over RoI and for the period of interest, and additionally experimental (i.e., Ansmann et al., 2011; Weinzierl et al., 2016) and climatological (Marinou et al., 2017) studies over the domain. However, we would like to thank the reviewer, for it is clear that the section of the manuscript needed improvement. Thus the sentence is modified accordingly in lines 426-428, page 14 of the revised manuscript:

"*The intercompared profiles are in a good agreement, with the simulations falling well-within the variability of the dust observations, although discrepancies are also present, especially close to the dust sources (Fig.9(b) – region I), and within the upper free Troposphere (Fig. 9(b) – region III).*"

**L 403-407 This discussion sounds like the observations are the main cause for model-observations discrepancies. I understand that this discussion is done to provide a justification why only Region II has been assessed. I suggest to revise the wording to avoid misinterpretation.**

The reviewer is right on his guess, and we would like to thank the reviewer for the comment. Following the comment, and in order to avoid possible misinterpretations, the following section from the manuscript is modified in line 428-430, page 14 of the revised manuscript:

*"The assessment of the different model experiments against the ESA-LIVAS pure-dust product is performed in the region between 1.5 km and 6.4 km a.m.s.l. (Fig. 9 – region II), to avoid possible biases propagating into the analysis (i.e., complex topography and surface returns-region I, SNR and tenuous aerosol layers – region II)".*

**L 418 "acknowledged" is not the right word here, neither "transport code".**

Absolutely, we proceed revising the related text with more appropriate wording in line 440, page 15 of the revised document:

*"In this study we extend the particle size range which is applied in the transport parameterization in GOCART-AFWA dust scheme of WRF, to include particles with diameters up to 100 μm.."*

**L 440 "(two times the particle major semi-axis)" seems out of place.**

We have removed this part revisiting the section of Discussion base on the reviewer’s and other reviewers’ suggestions.

**Discussion: I believe that much of the discussion around the different processes that might affect particle transport should go into the introduction. Only the discussion around the percentages in reduced settling these processes might account for should remain in the discussion.**

We would like to thank the reviewer for the suggestion, we have put a lot of effort in revising the Discussion Section, hoping that it is better and more understood. Bellow is the part of the Discussion (see lines 436-503, pages 15-17 of the revised manuscript):

*“The frequent presence of large desert dust particles (D>20 μm) far from their sources, is well established by numerous observational studies over the last decade (van der Does et al., 2018; Liu et al., 2018; Ryder et al., 2013, 2018, 2019a; Weinzierl et al., 2009, 2011, 2017b). However, the processes that result in the particle retainment in the atmosphere, and subsequently their travel at greater distances than predicted, remains unrevealed. In this study we extend the particle size range which is applied in the transport parameterization in GOCART-AFWA dust scheme of WRF, to include particles with diameters up to 100 μm. The evaluation against airborne in situ observations of the size distribution shows that larger particles are underestimated, both above their sources and far from them. This suggests that there are atmospheric processes that are not taken into account in the model simulations. We investigate the effect of reducing the settling velocity of the dust particles due to these unknown processes, and we see that for a reduction of 60% and (especially for) 80%, the simulations of the PSD in Cape Verde are improved with respect to the observations. The reduction of 80% correspomds to a reduction in settling velocity of 0.0066 m/s for particles with D between 5.5 and 17 μm, which is double than the value reported by Maring et al. (2003) for similar sizes. It should be noted though that Maring et al. (2003) derived this settling velocity using observations that were taken with a five-year difference. Ginoux (2003), has also reported an improvement in model simulations for a reduction in settling velocity of approximately 45% and 60%, for particles with diameters 10 to 30 μm. The differences in the model resolution, the dust scheme and the drag coefficient in Ginoux (2003) compared to this study, could cause the different values of the required corrections in the settling velocities. The difference with the values suggested herein can mainly be attributed to the different drag coefficient used in Ginoux (2003), which results in lower settling velocities for the spherical particles. More recently, Meng et al. (2022) performed a similar study, where after reducing the settling velocity by 13% for accounting for particles’ asphericity based on Huang et al., (2020), they performed sensitivity tests reducing the dust particles’ density from 2500 kg m-3 to 1000, 500, 250 and 125 kg m-3. They found that a decrease in the modelled dust aerosol density by 10-20 times its physical value (i.e., from 2500 kg m-3to 250-125 kg m-3) is needed to improve the comparison between the model and the long-range dust observations of coarse*

*particles. A 10 times reduction in particles' density is almost equal to a 90% reduction in the settling velocity (starting from the Clift and Gauvin (1971) drag coefficients and assuming conditions of U.S. Standard Atmosphere, Fig S5). It is clear that a huge reduction in the settling velocity in both the Meng et al., (2022) methodology and this work is required, although the physical processes occurring to explain this reduction are not clear.*

*One of the processes proposed in the literature to explain the longer atmospheric lifetimes of large mineral dust particles is the particle asphericity. Ginoux (2003) compared randomly-oriented prolate spheroids and spheres of the same cross section. They showed that spheroids fall slightly slower than their spherical counterparts, with their difference being negligible for spheroids with aspect ratio values less than 5.*

*Huang et al. (2020) compared randomly-oriented ellipsoids and spheres of the same volume. They showed that ellipsoids fall around 20% slower than spheres.*

*Mallios et al. (2020) compared prolate spheroids and spheres of the same maximum dimension, and of the same volume. Moreover, they did not assume randomly-oriented particles, but particles of specific orientation (horizontal and vertical). They showed that the results of the comparison change when the maximum dimension or the volume-equivalent size is used in the comparison. Prolate spheroids, with aspect ratio values in the range of 1.4-2.4, fall slower than spheres of the same maximum dimension, regardless of orientation, with the relative difference between the settling velocities reaching the value of 52%. On the other hand, prolate spheroids, in the same aspect ratio value range, fall faster than spheres of the same volume, regardless of orientation. The comparison with in situ observations of the maximum dimension of particles is not so common, since most of the in-situ measurements do not provide the sizing of the particles in terms of their maximum dimension, with some exceptions, as e.g. the observations shown in van der Does et al. (2016) of individual giant mineral particles (larger than 100 μm in maximum dimension).*

*All the above show that more work is needed for the definite and accurate quantification of the particle asphericity effect on their settling. Nevertheless, there are strong indications pointing that aspherical particles remain in the atmosphere longer, and that asphericity can be one of the reasons for the differences between the modelling results and the observations.*

*Another process that can influence mineral dust settling has to do with the electrical properties of dust particles. The dust particles are charged in the atmosphere either due to the attachment of atmospheric ions on them (Mallios et al. 2021b) or/and due to collisions, a process known as triboelectric effect (Ette, 1971, Eden and Vonnegut, 1973, Mills, 1977, Jayaratne, 1991). Moreover, there is a large-scale atmospheric electric field, due to the potential difference between the lower part of the Ionosphere and the Earth's surface (Rycroft et al., 2008). The electric field is modified by ion attachment process (Mallios et al. 2021b) or by the charge separation caused by updrafts (Krauss et al., 2003). Therefore, electrical forces are generated that might influence the particle settling process by balancing the gravity or changing the particle orientation. The quantification of the particle's electrical properties is still an open question.*

*Another possible source of error in the gravitational losses simulated by the model, proposed by Ginoux (2003b), is the numerical diffusion in the advection equation of gravitational settling. Since in the GOCART-AFWA dust scheme of WRF (and WRF-L) a first-order upwind scheme is adapted for the gravitational losses, which is rather* *diffusive, an investigation of the possible improvement on the results by the replacement of the scheme with a less diffusive would be of interest.*

*A possible limitation of this study is the accuracy of the PSD which is used for the distribution on the model transport bins of the emitted fluxes. The simplification in the assumption that the shape of the PSD at 1km above the sources remains unchanged in lower heights near the ground, could possibly introduce errors in the representation of the presence of dust particles aloft.*

*In any case, the proposed scheme presented here, provides a useful tool for the investigation of the physical processes in the transport of coarse and giant particles, along with their impacts on other physical processes in the atmosphere, such as ice nucleation and radiation interactions. The artificial reduction in the settling velocity is not attributed to a known physical mechanism (although results from the past literature reveal some candidates that can give results on the same order of magnitude). Thus, despite the encouraging results, more research is needed towards understanding the physical or numerical processes driving this finding, including the estimation of the impact of non-spherical particles, electricity, the radiation impact on thermodynamics and the disturbance of the mass balance due to the numerical diffusion."*

**L 482 losses instead of loses**

Done.