We would like to thank the anonymous referee for his comments mentioning different points listed below. The reviewer's comments are in black, and the answers are in red. New information and explanations in the new version of the article are italicized.

Anonymous Referee 1

The manuscript explores the impact of neglecting the representation of aerosol scattering in the longwave spectrum on the simulations of a Global Climate model. The radiative impact of longwave aerosol scattering is analysed using a 30-year integration of the ARPEGE-Climat atmospheric global climate model with prescribed boundary conditions. The authors analyse a set of model variables and their change between the simulation that includes longwave scattering and the simulation neglecting it.

The topic is of certain interest to improve the quantification of the uncertainty in aerosol radiative forcing on the Earth radiative budget and of the role of assumptions in the radiative transfer modelling. The paper is well organised and the methodology sufficiently clear.

My main issue with the current version of the manuscript is a lack of in-depth analysis of some of the main impacts observed when aerosol longwave scattering is enabled in the radiative computations. In particular, the change in low and high cloud fraction displayed by the model is puzzling because no mechanism behind it is discussed. Previous studies (e.g. Dufresne et al. 2002) suggest that the impact of longwave aerosol scattering on the heating rate profiles is relatively small: is this the case also in this study? Modification in the lower atmospheric stability is mentioned as one reason to explain the increase in low level cloud fraction. It would be interesting to see model data to support this hypothesis. Are surface temperature changes such as the ones reported here, enough to sustain the observed modification in the cloud fraction? Or is there any other feedback at play?

Thanks for this suggestion, we acknowledge the first version submitted did not provide in-depth analysis of the impacts on climate variables, notably to explain the changes noted in the Sahel in September. Therefore, the ARPEGE simulations have been relaunched to get additional diagnostics and thus providing new answers. The vertical velocity (wap), temperature and specific humidity vertical profiles are presented below in Figure 1. This figure shows that taking into account the LW scattering of aerosols leads to a significant reduction in temperature below 700 hPa, which in turn tends to stabilize these lower atmospheric layers. Indeed, negative values of wap correspond to convection, and as these values are less negative with the LWAS simulation below 700 hPa, this reflects a decrease in convection when the LW aerosol scattering process is activated. This drop in low-level convection, combined with a significant rise in humidity, has resulted in a stabilization of the lowest atmospheric layers and an increase in low clouds over the Sahel in September. Conversely, above 700 hPa, we can observe a rise in temperature, induced by LW aerosol scattering, which leads to a significant increase in convection. This increase in convection, coupled as before with a rise in humidity, favors high clouds and convective rain over the Sahel in September.

The new version includes these explanations as follows:
Page 9: *"Figure A6, which presents the vertical velocity (wap), temperature and specific humidity vertical profiles over the Sahel during September, shows that the significant reduction in temperature below 700 hPa over this region reduces convection in the lowest atmospheric layers (wap values are less negative in the LWAS simulation below 700 hPa). This drop in low-level convection, combined with a significant rise in humidity, has resulted in a stabilization of the lowest atmospheric layers and an increase in low clouds and convective rain over the Sahel in September. Conversely, above 700 hPa, Figure A6 highlights a significant temperature rise, which leads to a significant increase in convection. This stronger convection, coupled with a humidity augmentation, also favors high clouds and convective rain over the Sahel in September."*

The impact of LW aerosol scattering on the LW heating rate (named tntrl) profiles has also been studied and summarized in Figure 2 below. This figure clearly shows a small impact of the LW aerosol scattering on this heating rate, and this result is consistent with the study of Dufresne et al. 2002. The only significant impact is between the surface and 700 hPa (consistent with the vertical coarse aerosol concentration profile, see also Figure 2) during July, which is the month with the highest AOD (0.55). On the other hand, no significant change is visible in September (month studied in detail in the article). Compared to the study of Dufresne et al. 2002, the tntrl profiles show lower values (in absolute terms) because Dufresne et al. 2002 provide tntrl for an AOD of 1, whereas our tntrl correspond to an AOD of 0.55 (July) and 0.47 (September). The use of different asymmetry parameters between these two studies may also partly explain these differences in tntrl.

The new version includes these explanations as follows:
Page 9: *"The impact of the aerosol scattering in the LW spectrum on the LW heating rate (named tntrl) has also been studied over the Sahara region (see Figure 2), and is found to be relatively weak, which is consistent with the study of Dufresne et al. 2002. The only significant impact is between the surface and 700 hPa, consistent with the vertical coarse aerosols concentration profile, in July, which is the month with the highest AOD (0.55) over the Sahara region. On the other hand, no significant change is visible in September."*

These two figures have also been added in the appendix to the article.

I think that to support the conclusion that climate simulations should explicitly include longwave aerosol scattering, a more complete description of its impacts on the model fields would be helpful.

Radiative and climatic impacts of aerosol scattering in the LW spectrum are now better understood and described in the article, thanks to new figures showing vertical profiles of LW heating rate, vertical velocity, temperature and humidity. In addition to the elements in response to the first comment above, a sentence has been added in the conclusion to mention the impact of convection changes: *"This increase in low clouds is the result of stronger stratification in the lower troposphere, which is a consequence of weaker convection at these altitudes."*

The language throughout the text is generally clear, but I suggest a double check to improve the text in places (few suggestions in the specific comments below).

The text has been rechecked and enriched with suggestions from the two reviewers.

Specific comments:

Abstract, line 1: “The few studies that considered aerosol scattering in the long-wave (LW) typically relied on artificially increasing it.” Please explain or rephrase, it is not clear what it is meant by “artificially increasing it”

This sentence has been clarified: *"The few studies that considered aerosol scattering in the long-wave (LW) typically relied on using simple corrective factors instead of including it in the radiative code."*

Abstract, line 8: “in line with the maximum coarse AOD” please clarify, e.g. “correlated with the largest AOD from coarse particles.”

This sentence has been clarified: *"correlated with the largest coarse AOD."*

Abstract, line 10: “However, during certain months and regions” -> ”However, during certain months and in certain regions”

Done.

Introduction, page 1, line 22: please indicate the reference for AR5. Also, AR6 should be explained above, where there is the first reference for the latest IPCC Assessment Report.

Done.

Introduction, page 3, line 64: Values in Dufresne et al. (2002) are for specific profiles and not global means though, right?

This is right, and has been clarified in the text. *"which is far from the 3 to 5 W m-2 cited in Dufresne et al. (2002) for standard vertical profiles"*

Section 2.2: In the discussion of the results, the impact of the longwave aerosol scattering is shown for all-sky and clear sky conditions. Perhaps it could be mentioned here how the two contributions are calculated (i.e. selecting clear sky areas or with separated clear sky computations?)

New information on clear-sky and all-sky diagnostics has been added to section 2.2: *"The various radiative diagnostics provided in this study have been computed in all-sky conditions and in clear-sky ones, as classically done. In clear-sky conditions, only clouds are removed, surface temperatures and water vapor remaining unchanged."*

Section 3, line 192: Differences in the RI for wavelengths above 20 microns is likely of minor importance: do spectral regions outside the IR window contribute significantly to the results shown in this study? Generally, only for extremely dry atmospheres the radiative effect of longwave scattering from aerosols is significant for spectral regions above 20 microns.

Indeed, the LW aerosol radiative forcing is maximum for wavelengths below 20 microns. However, Sicard et al. (2014) also indicated that large particles have a non-negligible effect in the 17 to 22 μm range at the TOA. It was therefore important to update our desert dust IR values over the entire spectrum of long wavelengths, from 3 to 40 μm.

Section 3, line 196: Since the sea salt results are not discussed, perhaps this can be removed/shortened?

This part about sea-salt RI has been shortened.

Section 5, line 251: Please clarify what is it meant "this daily minimum surface temperature increase is much smaller than the extent of the LW surface radiation increase." Does this refer to the area showing changes respectively in LW fluxes and surface temperature or the magnitude?

This sentence has been clarified and replaced by: *"It is interesting to note that the area covered by this daily minimum surface temperature increase is much smaller than the area covered by the LW surface radiation increase."*

Section 5, line 254 and 269: These results could be interesting and deserve more in-depth analysis in my opinion. Is there an interaction with the strength/position of the ITCZ or/and the West African Monsoon region? Also, this is the region where there is a significant negative bias in AOD compared to AERONET, does this have an impact on the results?

Indeed, aerosols influence the dynamics of the African monsoon, particularly the West African Monsoon, through various mechanisms such as radiative forcing, atmospheric circulation or cloud microphysics (Roehrig et al. 2013, Solmon et al. 2021). For example, biomass burning aerosols from Southern Africa have been shown to affect the West African Monsoon by inducing regional scale and inter-hemispheric dynamical feedbacks (Solmon et al. 2021). These feedbacks can alter the strength and position of the monsoon system. Moreover, Solmon et al. 2008 have shown that Lw scattering by aerosols leads to heating of the atmospheric layer where aerosols are concentrated, which can stabilize the atmosphere, suppress convection and reduce monsoon rainfall. A further study on the LW aerosol scattering impacts on the African monsoon would therefore be interesting. The AOD bias present over this region may also have an impact on the results presented here and reducing this bias would therefore allow for a better estimate of the impact of LW aerosol scattering.

Section 5, line 282: "In clear-sky conditions, LW scattering of aerosols has less impact on radiation." Doesn't this contradict what said at line 247 "Our results indicate that they are even more significant in clear-sky conditions?" Please clarify.

Indeed, these two sentences may seem contradictory. Line 247, the analysis is based on the months of March, May, July and September, whereas line 282 we refer to the annual average. These sentences have been clarified: *"Our results indicate that they are even more significant in clear-sky conditions over these four months"* and *"In clear-sky conditions, and as an annual average, LW scattering of aerosols has less impact on radiation."*

Section 5, line 290: This makes the simulation results interesting but somewhat difficult to interpret. As far as possible within the current simulation, physical interactions between model variables should be analysed.

As explained above, new simulations have been carried out to provide new diagnostics (LW heating rates, vertical velocity, temperature and specific humidity vertical profiles) and have enabled us to go further in our analysis (see our response to the general comment).

Conclusions, line 313: “for turning on or off the 3D scattering of aerosols in the LW.” What is it meant by 3D scattering?

This sentence has been deleted in agreement with the following comment.

Conclusions, line 313: This information is mostly auxiliary to the current study, and I would not mention it in the main conclusions which should be focussed on the mean results of the impact of the explicit treatment of longwave scattering in aerosol radiative effects.

This part has been simplified and shortened.

Conclusions, line 334-338: An estimate of the different weight of these contributions to the general longwave aerosol radiative forcing would be interesting, to put in context the size of the effect analysed here. It could be added to the main discussion.

We agree it might be interesting to know which of these suggestions is the most promising, but it is difficult to estimate. Furthermore, these lines were more intended to suggest different ways of improving our climate models. Probably the results would depend on each model.

Figures

Figure 3: From the caption it sounds like the first column shows AOD differences, which had me confused. Please rephrase.

The legend of the figure 3 has been rephrased. *"Coarse AOD (550 nm, left column) and mean differences (1985-2014) between the LWAS and NOLWAS simulations (LWAS minus NOLWAS)"*

Figure 4: the symbols rlds and rlus have never been defined.

rlds and rlus are now defined in the figure caption.

Figure 5: The colours in the second panel are not very clear and it is difficult to discern the various lines. It is also not very clear what it is meant by “No significant changes in confidence intervals indicated in light color”. Is the light colour shading indicating the confidence interval or the significance of the differences between the two runs? How is this computed? Please clarify here or in the mean methods section.

The colours of the second panel have been changed. The dashed lines of clear-sky lines have also been modified for greater legibility. The light colour shading indicates the confidence interval and it is calculated as follows: 1.96*standard deviation/square root of number of years.

Figure A3: it should be "same as Figure 4"

Done.

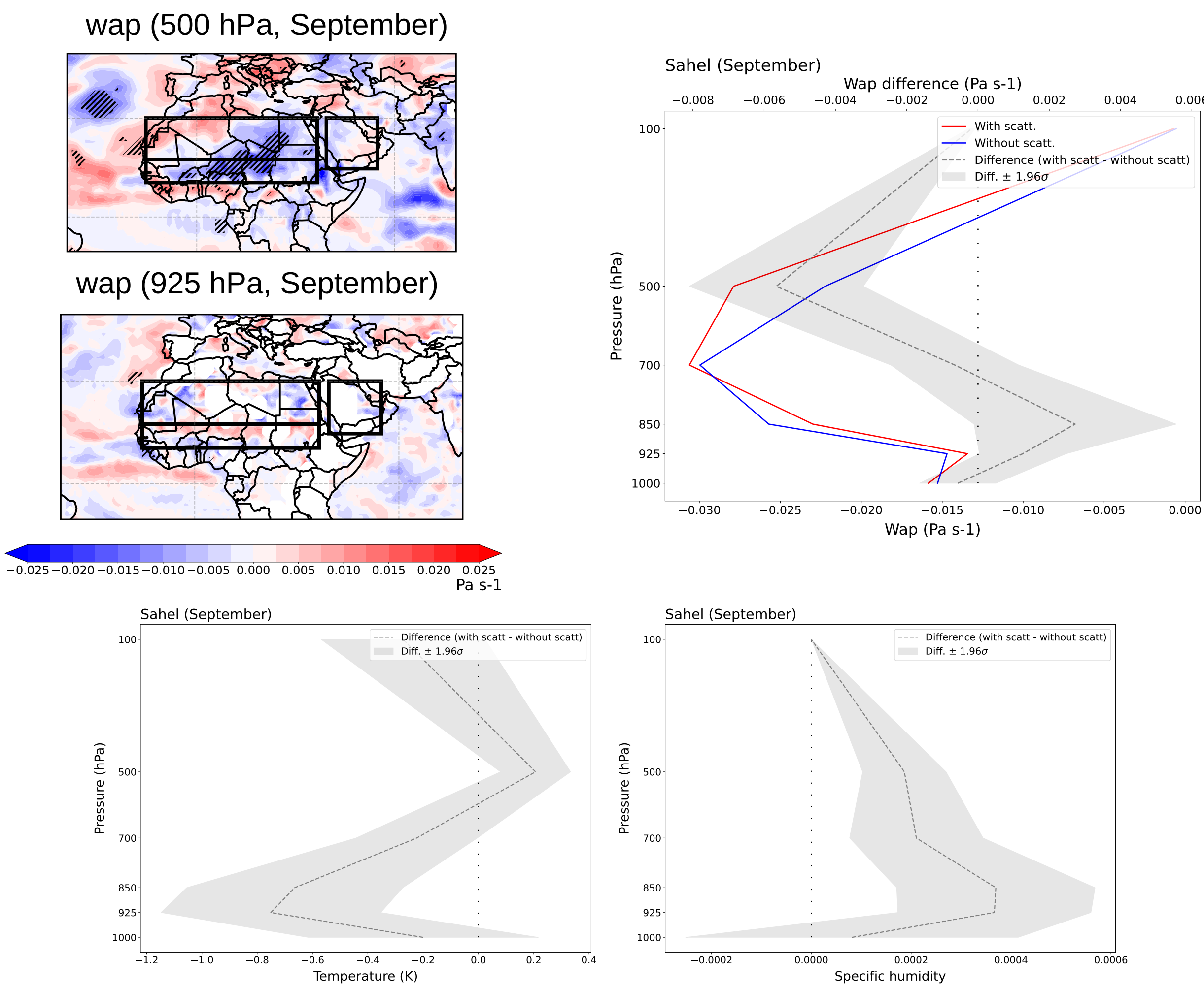

Figure 1. Mean differences (1985-2014) between the LWAS and NOLWAS simulations (LWAS minus NOLWAS) in vertical velocity (wap, 500 and 925 hPa, top left). Vertical profiles of vertical velocity (top right), temperature (bottom left) and specific humidity (bottom right) over the Sahel in September for the LWAS (red) and NOLWAS (blue) simulations. Difference between these two simulations (LWAS minus NOLWAS) is shown (dashed grey line). Confidence intervals for no significant changes indicated in grey light color (Student’s t-test, 0.05 level).

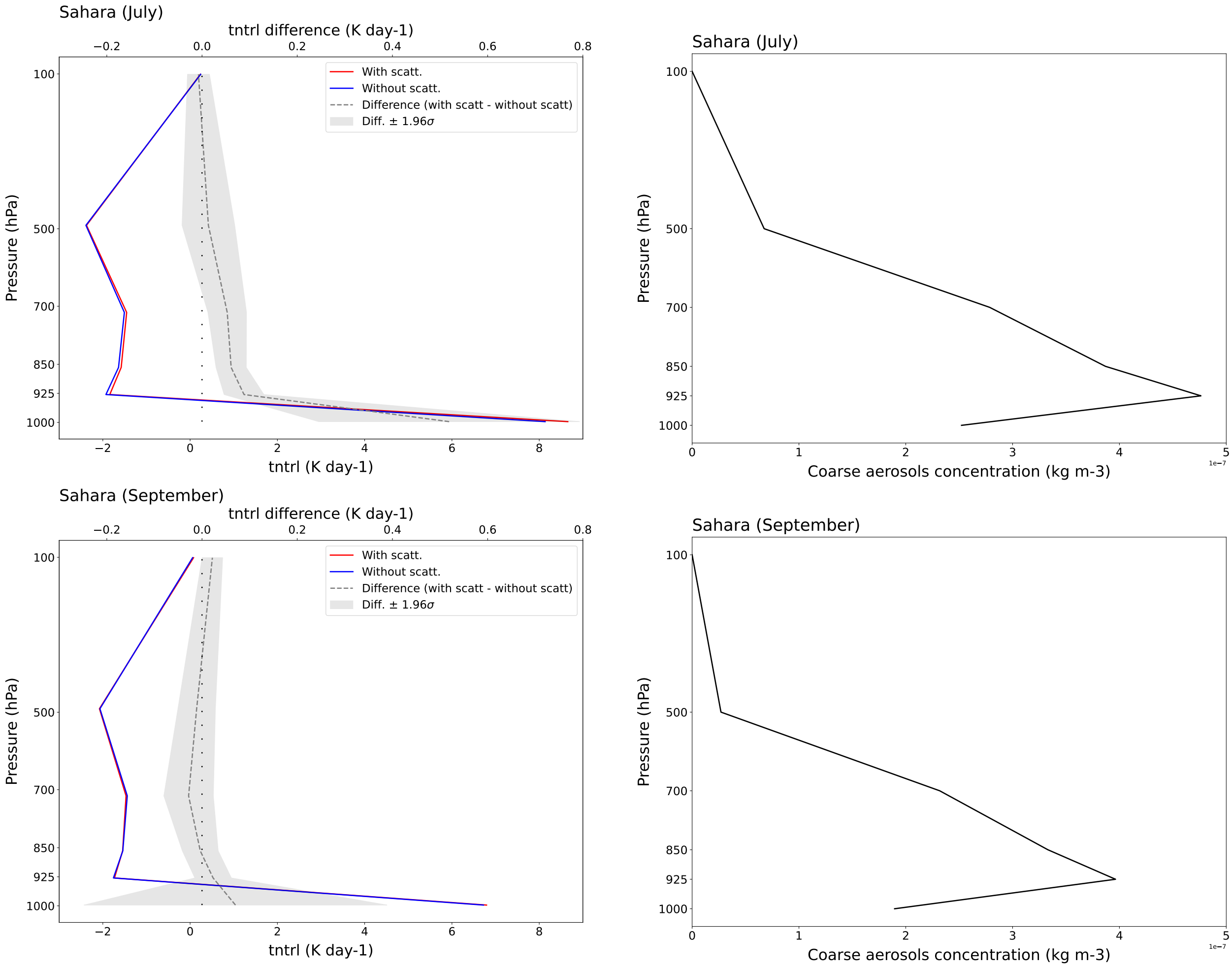

Figure 2. LW heating rate (tntrl) vertical profiles over the Sahara region in July and September for the LWAS (red) and NOLWAS (blue) simulations. Difference between these two simulations (LWAS minus NOLWAS) is shown in grey. Confidence intervals for no significant changes indicated in grey light color (Student's t-test, 0.05 level). Associated coarse aerosols concentration vertical profiles are shown on the right.

We would like to thank the anonymous referee for his comments mentioning different points listed below. The reviewer's comments are in black, and the answers are in red. New information and explanations in the new version of the article are italicized.

Anonymous Referee 2

This paper is an important advance in providing better radiative transfer schemes in climate models. The redo of ARPEGE-Climate with longwave thermal IR scattering for large dust aerosols represents new work and is timely. The authors did a very nice job in presenting overall, with only minor English language issues. The authors can clean up some of the language issues and clarify the issue of monthly climatologies. The other problem is with the diagnostics that remove clouds ('clear sky') from a self-consistent climate model but assume that surface temperatures and water vapor are unchanged. These diagnostics should be removed or justified.

New information on the definition of clear-sky and all-sky diagnostics has been added to section 2.2: *"The various radiative diagnostics provided in this study have been computed in all-sky conditions and in clear-sky ones, as classically done. In clear-sky conditions, only clouds are removed, surface temperatures and water vapor remaining unchanged."*

Besides, we acknowledge the disadvantage of the clear-sky diagnostics is that they do not take into account the effects of water vapor, which is important for LW radiative budget. Therefore, this point has been clearly mentioned and Table 1 has been simplified, the results obtained under clear-sky conditions have been put in appendix.

Overall the paper is well written, an important contribution, and nearly ready to publish.

L35-48: This discussion is important here and should do a better job of helping the reader understand the basic physics of the atmosphere and radiative transfer:

- the 8-12 micron window is so well known because H2O and other gases blanket the longer wavelengths and shorter wavelengths; it has nothing to do with the aerosol properties.

We agree with the reviewer's comment. The following sentence has been modified in the text: *"Both Dufresne et al. (2002) and Sicard et al. (2014) underlined that the LW aerosol RF is maximum at wavelengths between 8 and 13 µm, as expected, while Sicard et al. (2014) indicated that large particles have a non-negligible effect in the 17 to 22 µm range at the TOA."*

- it would be nice to discuss what size aerosols need to be to affect this IR window (> 2 microns?), including a discussion of their Q vs effective radius here.

The impact of aerosol size on LW radiation is discussed in the fourth paragraph of the introduction, where we provide information from several publications. Regarding their Q, dust particles are generally weakly hygroscopic, and their ability to absorb water decreases with increasing size (Kumar et al. 2011).

L119: Since you do not calculate the scattering phase function for the aerosols, you are limited to RRTMG's two-stream scattering, which causes heating biases (at least in the uv-vis) over bright albedo regions (Hsu and Prather, 2021, Assessing uncertainties and approximations in solar heating of the climate system. JAMES, 13, e2020MS002131. doi: 10.1029/2020MS002131). Interestingly enough Hsu & Prather did not do LW scattering but only solar. There is nothing that can be done about the use of 2-stream here alas. The other 4+ stream RT codes are at GFDL and CCC.

Thank you for this interesting information. A sentence has been added to the text: *"The use of two-stream scattering in RRTM could also cause some heating biases in the UV and visible spectrum (Hsu and Prather, 2021).*

L153: I am confused as to whether you used AERONET to evaluate the monthly climatology used in your LWAS calculations or to evaluate the daily TACTIC results used to get the monthly means – that would make more sense, then you can use daylight only model data. Can you please evaluate the issues of diurnal aliasing with your TACTIC model? ARPEGE-Climat is using a climatology – right? Also, is the monthly climatology different for each year?

In this article, AERONET data are used to evaluate the 3D monthly climatology of aerosol concentrations used in the LWAS and NOLWAS simulations. The 10-year simulation using TACTIC, on which this climatology is based, was also evaluated with AERONET data in a previous article (Drugé et al. 2022). The issues of diurnal aliasing with our TACTIC model were notably mentioned in our previous article (Drugé et al. 2022). The climatology used here is the same for all years, but evolves monthly over the course of the year.

L162-165: This algorithm is a bit confusing, please make it clear what was done.

In order to have the most accurate comparison with the model, we decided to keep only AERONET monthly data with at least eight daily values to derive the mean of each month, and for a given month we keep only the stations with at least 3 monthly values over the 2000-2020 period. This data selection process has been clarified in the text.

L172. Since dust, esp. large dust, is non-spherical, please comment on the errors resulting form Mie assumption as opposed to using T-matrix or PingYang's ice crystal codes to get the scattering phase function.

Several studies, such as Bellouin et al. 2004 or Colarco et al. 2014, have shown that considering dusts as spherical in climate models has little impact on the DRE at the TOA. This information is given at the end of the fourth paragraph of the introduction.

L173: Glad to see new work on the RI of aerosols.

L218: I thought that the ARPEGE-Climat model being used here for LW scattering is just using an aerosol pre-calculated climatology – what does this r value mean – it should be daily, not monthly means I would expect. If you are evaluating the TACTIC run to generate the climatology, then this discussion needs to be revised.

Correlation coefficients are calculated here to assess the monthly AOD simulated by the ARPEGE-Climat model, which effectively uses a 3D monthly climatology of aerosol concentrations, against the monthly climatology of AERONET AOD data.

L238: "several meteorological fields" You have only one or two meteorological fields (with and without LWAS). Maybe you mean diagnostics? or quantities?

Yes, we're talking about diagnostics here.

L243: These 4 months "cover" or "span" the period of max AOD, they do not "correspond" to it – the latter implies that they are the four months of max AOD.

Done. The sentence has been modified.

L245: "clear-sky" conditions are artificial and only in a model, what is the purpose here? You should focus on "all-sky" conditions. Also you need the full climate response in ARPEGE since the surface T is changing. This discussion is odd – who cares if it is more significant in clear-sky? We are talking climate and monthly mean aerosols!

We have reoriented slightly our study which now focuses mainly on results under "all-sky" conditions. We have simplified our Table 1 but we kept the "clear-sky" section in Appendix as our results under "clear-sky" conditions show that the LW scattering of coarse aerosols has a direct impact on radiation. Furthermore, this distinction between "all-sky" and "clear-sky" is also often used in the scientific literature, so we thought it would be useful to provide this information, at least in the appendix.

L255: Here is the climate response – excellent.

L260: Very interesting climatic shift due to the LWAS, how significant is the change in high cloud (Fig 5) or convective rain – I did not notice any discussion of ensembles or climate variability?

In this study, the significance of changes between the two simulations (LWAS and NOLWAS) is tested using a Student's t-test (0.05 level). Indeed, a larger study, with several climate models or an ensemble of simulations would be very useful and interesting to support or not the different results of this study.

L304: How robust are these differences to issues of climate variability, and would having an interactive aerosol calculation (vs. monthly mean) change these results? e.g. large dust aerosol loading depends on wind shear, lack of cirrus, etc? Also the wind/rain biases in L334.

This study is based on the analysis of simulations carried out over a period of 30 years, which makes it possible to obtain robust and significant results despite climate variability. Having an interactive aerosol calculation could modify these results. Indeed, as these results are obtained with aerosol AOD averaged over the month, AOD peaks are not taken into account. Use an interactive aerosol scheme would make it possible to study the impact of aerosol scattering in the LW spectrum during strong wind events generating high dust AOD loads, or during heat waves, etc.

Correcting for wind and rain biases in the model would also provide a better estimate of the impact of aerosol LW scattering. In the northern part of the region studied in this study, a correction of these biases would result in a less strong AOD and therefore potentially smaller impacts and vice versa in the southernmost part of this region. It is important to note, however, that the strongest effects are not always co-localized with the strongest AODs.

L313: Does ecRad actually do 3D RT? (pardon my ignorance here)

The 3D effects of clouds are not taken into account in our simulations for reasons of computing cost. However, this option is available in ecRad with the SPARTACUS solver.

Table 1. The extensive comparison of All-sky vs Clear-sky is becoming too artificial. For SW, this is fine because water vapor does not affect much. Clouds are clearly correlated with the water vapor and hence just removing clouds without including their effect on water is misleading.

Table 1 has been simplified and the results obtained under clear-sky conditions have been put in Appendix. Moreover, new information and limitations on clear-sky and all-sky diagnostics have been added to section 2.2.

Figure 3. A lot of the colored signal here appears to be statistically not significant w.r.t. climate noise. There are some hatched areas, but most of your square are not. For Figure 4, the radiation is clearly significant, but the T is not.

In fact, not all diagnostics are affected in the same way by taking into account the LW diffusion of aerosols. These differences are discussed in the article. In addition, other diagnostics (LW heating rate, vertical velocity, temperature and specific humidity vertical profiles) have also been added and discussed in this study.

One odd question: does you model include LW scattering by cirrus and stratus? Can you comment on that impact (which would seem to be bigger issue than dust)?

Yes, the LW scattering by clouds is taken into account in our model. Cloud longwave scattering is frequently omitted in the radiation schemes of atmospheric models, even if it can increase longwave cloud radiative effect by around 10% globally (Costa and Shine, 2006).

150 Please finish the Dufresne 2002 reference by adding: 'doi:10.1175/1520-0469(2002)059<1959:LSEOMA>2.0.CO;21, 2002'

Done.