Response to **Anonymous Referee #3** concerning the paper "*Dust size parameterization in RegCM4: Impact on aerosol burden and radiative forcing*" (http://www.atmos-chem-phys-discuss.net/acp-2016-434).

November 30, 2016
Dear editorial and respected reviewer,

Thank you very much for reviewing our manuscript and providing us with such a constructive feedback. We believe that your comments helped us highlight some critical aspects of the paper and add important content which elevates the quality of our work. All the short comments and typographical errors were corrected in the new version of the paper, while comments that needed more explanation and additional material are discussed below. The structure of the responses includes (1) comments from Referee, (2) a detailed response (3) changes implemented in the new version of the paper. Quotes from the initial version of the paper are highlighted with pale red along with the corresponding page and lines. Quotes from the new version of the paper are highlighted with pale blue along with the corresponding page and lines. The specific phrases changed-modified are underlined for convenience. In cases where the quotes are discussed but not changed are highlighted with grey. I sincerely hope you will be fully satisfied with all the changes we have made.

Best Regards,
Athanasios Tsikerdekis

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1) I suggest to join all three datasets in the validation part. It makes the reader easier to see the difference between the two aerosol size bin discretization schemes in the view of the reference observational data. Of course, this holds only for those quantities, where observations are available.

We agree with the reviewer and therefore Figure 12 was updated and now includes the LIVAS DOD annual cycles along with the DUST4 and DUST12 experiments. Future readers can now directly compare DOD of LIVAS with the two experiments in the dust size bin discretization Section of the paper "3.2 Comparison of 4-bin and 12-bin experiments". Although since the DUST12 experiment is not discussed in the Section "3.1 Evaluation", we believe it would be confusing to include it in prior plots. Also, the following phrase was updated:
P 14, L 27: Figure 12 shows the annual cycle of DOD for the DUST4 and DUST12 experiments.
P 16, L 1: Figure 12 shows the annual cycle of DOD for LIVAS, DUST4 and DUST12 experiments.

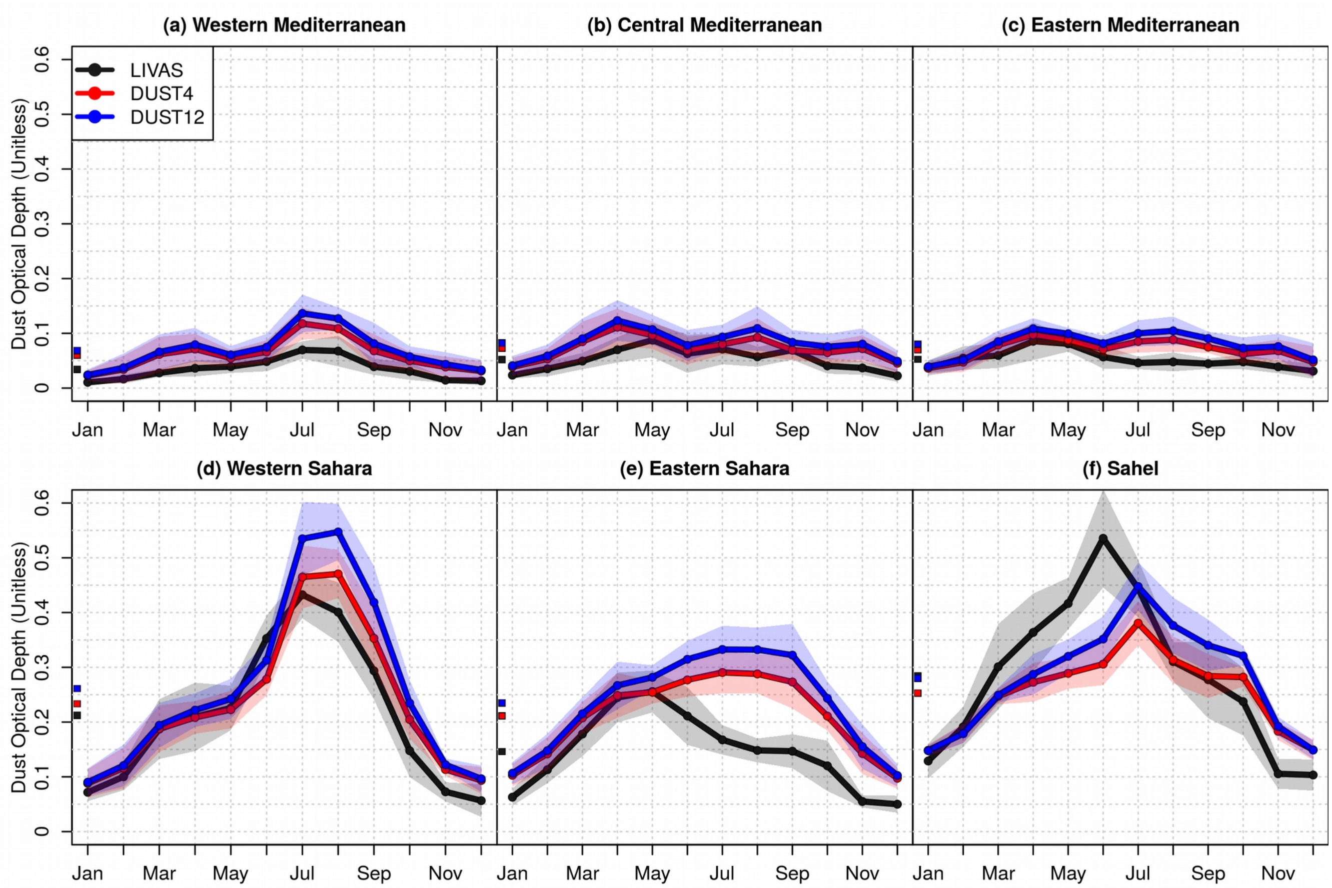

Figure 12. Dust optical depth annual cycle of LIVAS, DUST4 and DUST12 experiments for the period December 2006 to November 2014.

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2) The presented changes caused by the introduction of new aerosol size bin scheme are rather small. I agree with the other reviewer, that this requires a statistical significance test of the differences.

Thank you for highlighting the statistical significance issue. We have calculated the statistical significance of the differences using the monthly data for each grid point for the DOD, dust column burden and radiative forcing using the two-tailed paired t-test. In all variables and almost in all grid points the differences are statistically significant at the 95% confidence level (p.value < 0.05). We have also updated the text in the new version of the paper to highlight this issue. The plots shown below were not updated in the paper since we believe that they do not offer additional information to the reader; the vast majority of the grid points show differences that are statistically significant (shaded areas in the differences), hence we are just mentioning this in the text.

Pg 14, lines 13-20: The DOD percent increase is between 10.4% and 13% for all the subregions. Furthermore, there is a distinctive increase by 0.04 with the 12-bin model over the Sahara desert and especially along the Sahel region where the DOD values are higher (Figure 11c). In comparison with the DUST4 simulation the DUST12 simulation increases the deposition lifetime (column burden/total deposition flux) by 3.5 hours and 2 minutes for fine and coarse particles respectively. Consequently, that increases the dust column burden of fine (+4%) and coarse (+3%) particles (Figure 11f,i). The changes in the fine particles correlates better with the changes in DOD, because dust extinction coefficient is much higher for fine particles (<2.5μm) (Figure 1). Over the Middle East and the northern part of the Arabian Peninsula we observe a distinct increase on the coarse dust column burden by 10mg•m-2.

Pg 15, lines 17-26: The DOD percent increase is between 10.4% and 13% for all the subregions. Furthermore, there is a distinctive increase by 0.04 with the 12-bin model over the Sahara desert and especially along the Sahel region where the DOD values are higher (Figure 11c). In comparison with the DUST4 simulation the DUST12 simulation increases the deposition lifetime (column burden/total deposition flux) by 3.5 hours and 2 minutes for fine and coarse particles respectively. Consequently, that increases the dust column burden of fine (+4%) and coarse (+3%) particles (Figure 11f,i). The changes in the fine particles correlates better with the changes in DOD, because dust extinction coefficient is much higher for fine particles (<2.5μm) (Figure 1). Over the Middle East and the northern part of the Arabian Peninsula we observe a distinct increase on the coarse dust column burden by 10mg•m-2. The differences of DOD and column burden between the two experiment, calculated from the monthly data for each grid, are statistically significant at the 95% confidence level according to a two-tailed paired t.test for almost all the grid points of the simulated domain.

Pg 16, lines 11-13: Similarly, at the surface the positive radiative forcing rise by 0.08W·m-2 (3.0%) and 0.09W·m-2 (2.7%) in eastern and western Sahara and 0.9W·m-2 (6.3%), 0.08W·m-2 (4.8%) and 0.9W·m-2 (6.5%) in western, central and eastern Mediterranean (Figure 14f).

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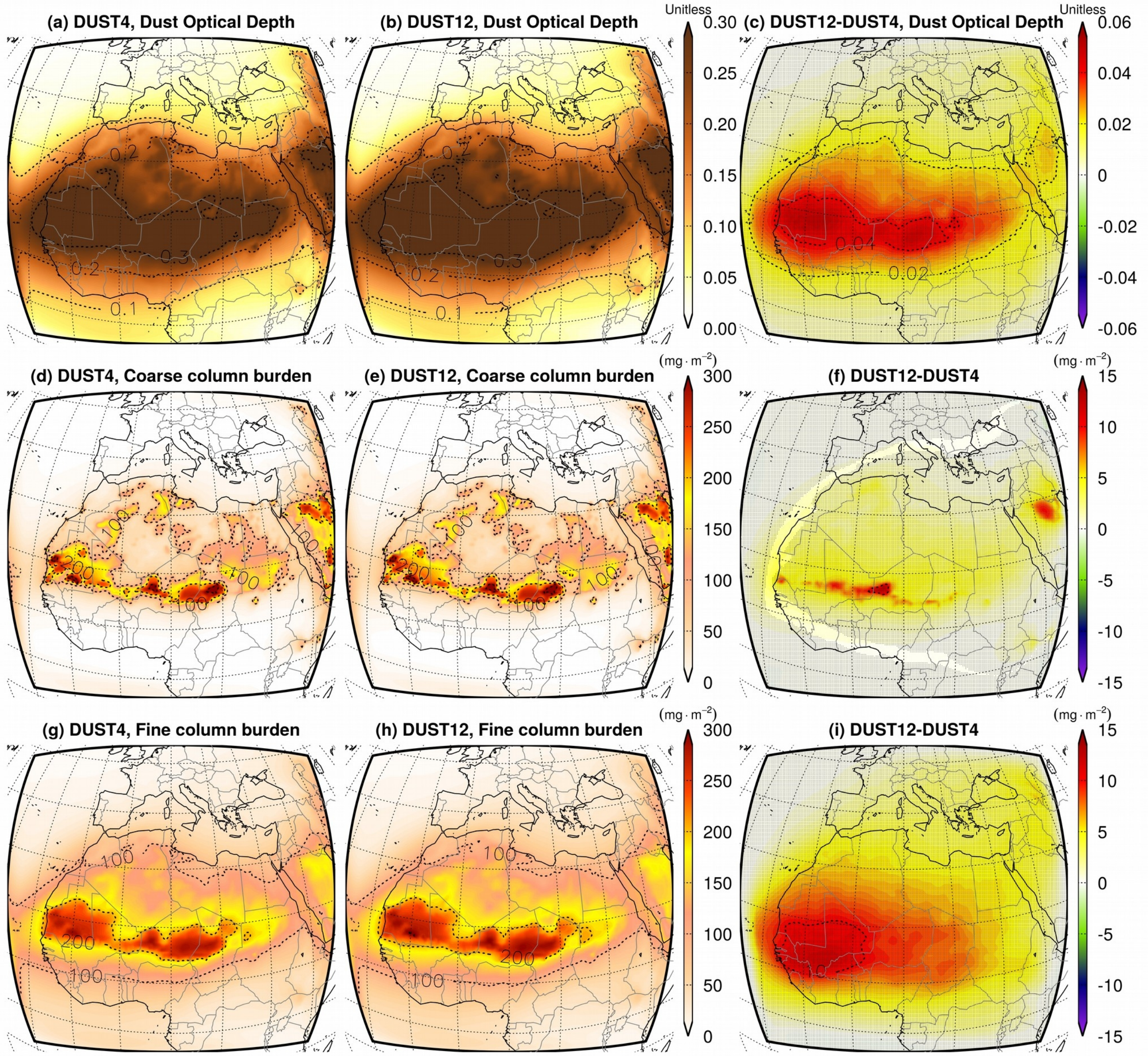
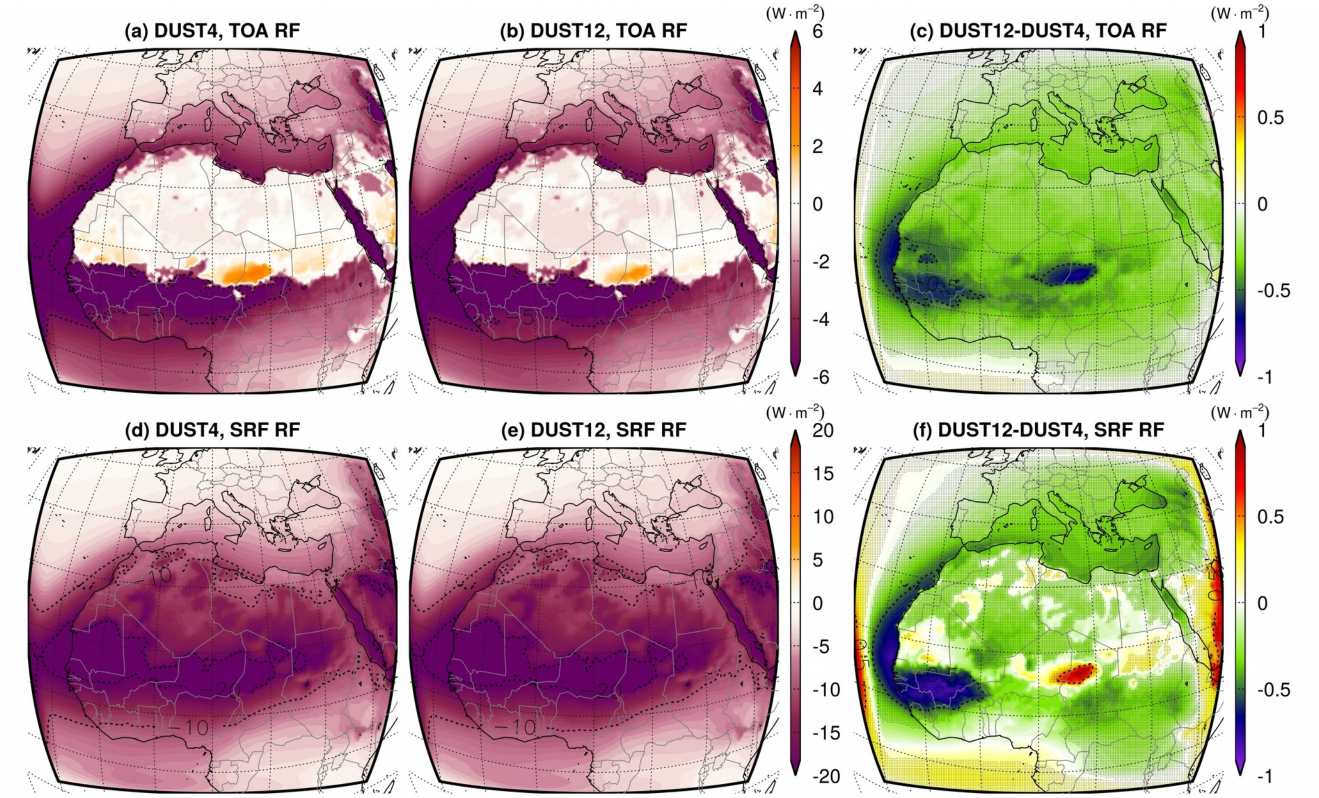
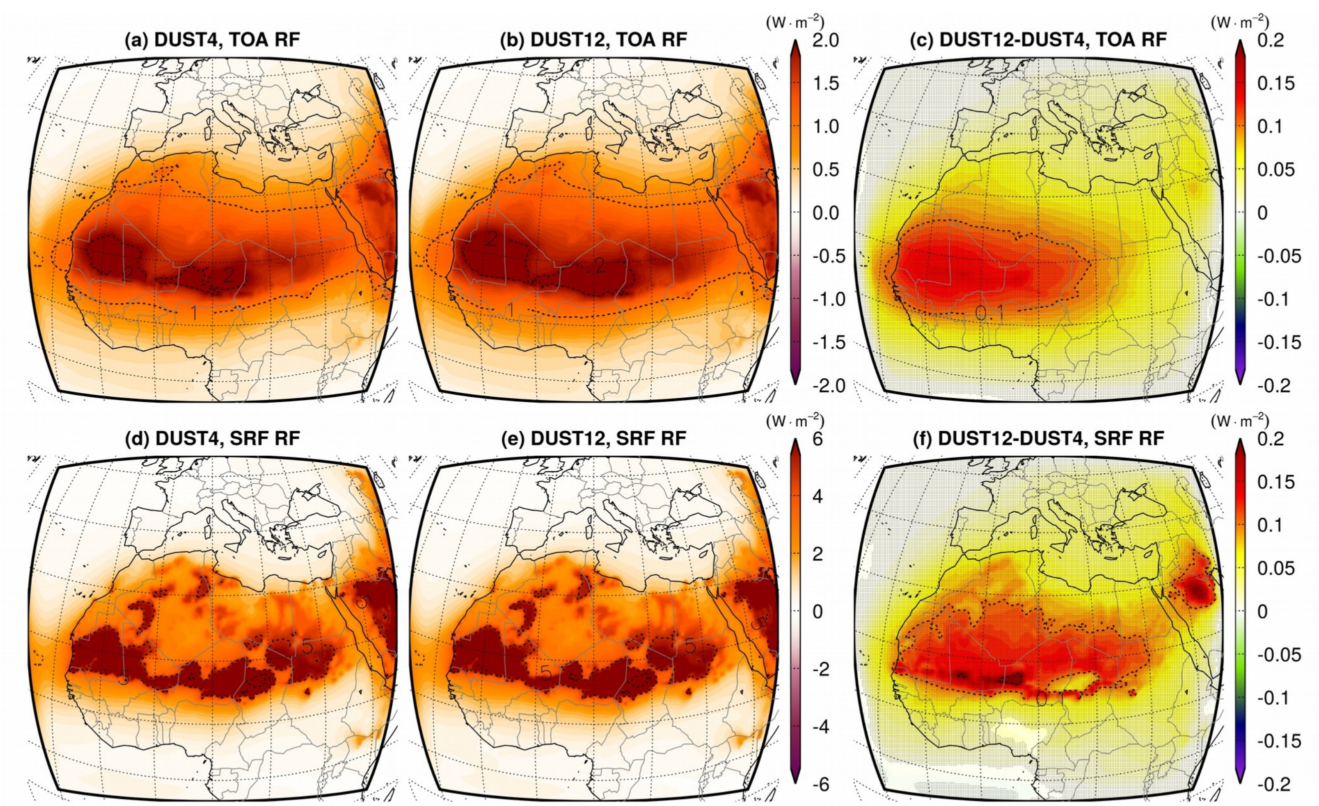


(a) DUST4, Dust Optical Depth
(b) DUST12, Dust Optical Depth
(c) DUST12-DUST4, Dust Optical Depth
Unitless
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
(d) DUST4, Coarse column burden
(e) DUST12, Coarse column burden
(f) DUST12-DUST4
(g) DUST4, Fine column burden
(h) DUST12, Fine column burden
(i) DUST12-DUST4
(mg · m⁻²)
300
250
200
150
100
50
0
15
10
5
0
-5
-10
-15



(a) DUST4, TOA RF
(b) DUST12, TOA RF
(c) DUST12-DUST4, TOA RF
(d) DUST4, SRF RF
(e) DUST12, SRF RF
(f) DUST12-DUST4, SRF RF
(W · m⁻²)
6 4 2 0 -2 -4 -6
1 0.5 0 -0.5 -1
20 15 10 5 0 -5 -10 -15 -20



(a) DUST4, TOA RF
(b) DUST12, TOA RF
(c) DUST12-DUST4, TOA RF
(d) DUST4, SRF RF
(e) DUST12, SRF RF
(f) DUST12-DUST4, SRF RF
(W · m⁻²)
2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5 -2.0
0.2 0.15 0.1 0.05 0 -0.05 -0.1 -0.15 -0.2
6 4 2 0 -2 -4 -6

3) Pg 3, lines 15-16: This statement is true, however please add 1-2 sentences on how this number affects the modeling of aerosols, at least in theory.

Indeed, adding a discussion at this point makes the initial statement more robust. Therefore, we have explained briefly why this is the case as it was suggested.

Pg 3, lines 15-16: An important component that affects the transport and the radiative properties of dust in climate modelling is the number of transport dust size bins.

Pg 3, lines 15-20: An important component that affects the transport and the radiative properties of dust in climate modelling is the number of transport dust size bins. Small dust particles, due to their weight, can travel over long distances and can efficiently reflect/backscatter the incoming shortwave solar radiation, while larger particles, with shorter atmospheric life, can effectively absorb and re-emit in the longwave spectrum. Thus, both the partitioning and the number of dust transport bins, used in atmospheric models, should carefully distinguish dust particles with contrasting radiative properties and transport characteristics.

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4) Pg 5, lines 25-26: So aerosols cannot move from one bin to another meaning that there is no aerosol fragmentation or aerosol coagulation?

Yes. The current state of the model assumes that dust particles retain their size and they do not fragment into smaller particles during transport. Thus remaining in the same bin throughout their atmospheric life.

Pg 5, lines 25-26: Each transported bin is considered as a distinct tracer, which assumes that there is no mixing between the dust size bins.

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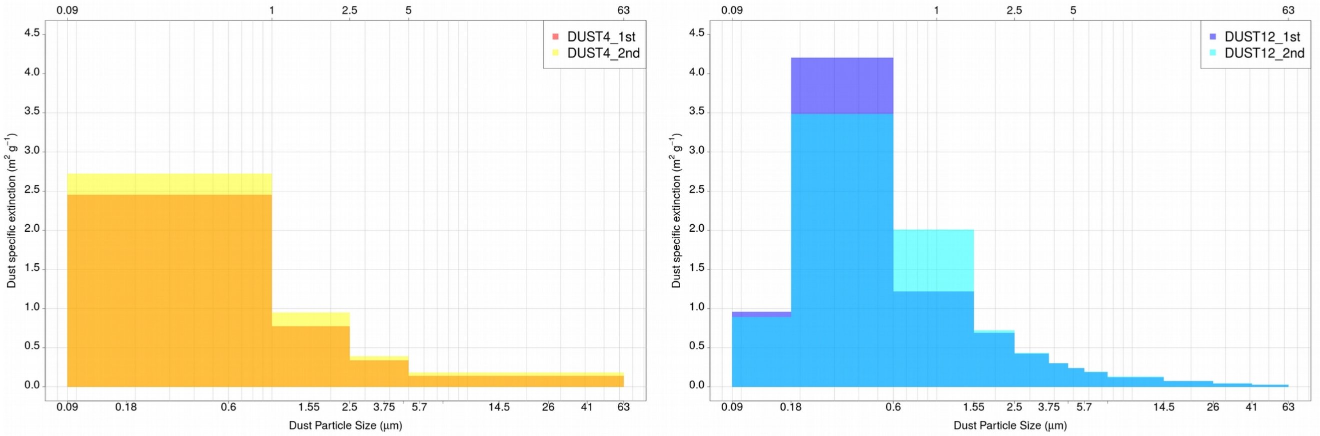
5) Pg 6, lines 5-7: I would be interesting to compare the presented optical properties with those obtained by using only one effective diameter – i.e. the one that describes the bin (the center of it).

Thank you for giving us the opportunity to discuss a more technical aspect of our work. The bin specific extinction coefficient is displayed below for 4 and 12 bins (left and right respectively). The 1st method uses as effective particle radius the mean diameter of each size bin in order to calculate the extinction coefficient, while the 2nd method calculates the extinction coefficient for multiple radii within the range of each size bin and average them in the end. The 2nd method is numerically more accurate and thus it was adopted in our paper. The highest differences between the two methods are observed in fine particles (<2.5μm) where the optical properties change rapidly with particle size.

These informations could be valuable for future reader we have added the following plot as supplementary material and cited it also in the main text:

Pg 6, lines 4-7: The differences for all the optical parameters are relatively small, because the calculations were performed for multiple effective particle radii within the range of each size bin and averaged in the end, instead of using the mean effective radius of each size bin. Using this method the optical properties between the two experiments are almost identical.

Pg 6, lines 10-13: The differences for all the optical parameters are relatively small, because the calculations were performed for multiple effective particle radii within the range of each size bin and averaged in the end, instead of using the mean effective radius of each size bin (FigureS 1). Using this method the optical properties between the two experiments are almost identical.



FigureS 1: Dust bin specific coefficient for 4 and 12 dust size bins. The first 1st method uses as effective particle radius the mean diameter of each size bin in order to calculate the extinction coefficient, while the 2nd method calculates the extinction coefficient for multiple radii within the range of each size bin and average them in the end.

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6) Pg 17, line 2: ..on emissions? I missed something in the manuscript? At this point, I would recommend to present an emission figure to gain some idea about its spatial distribution.

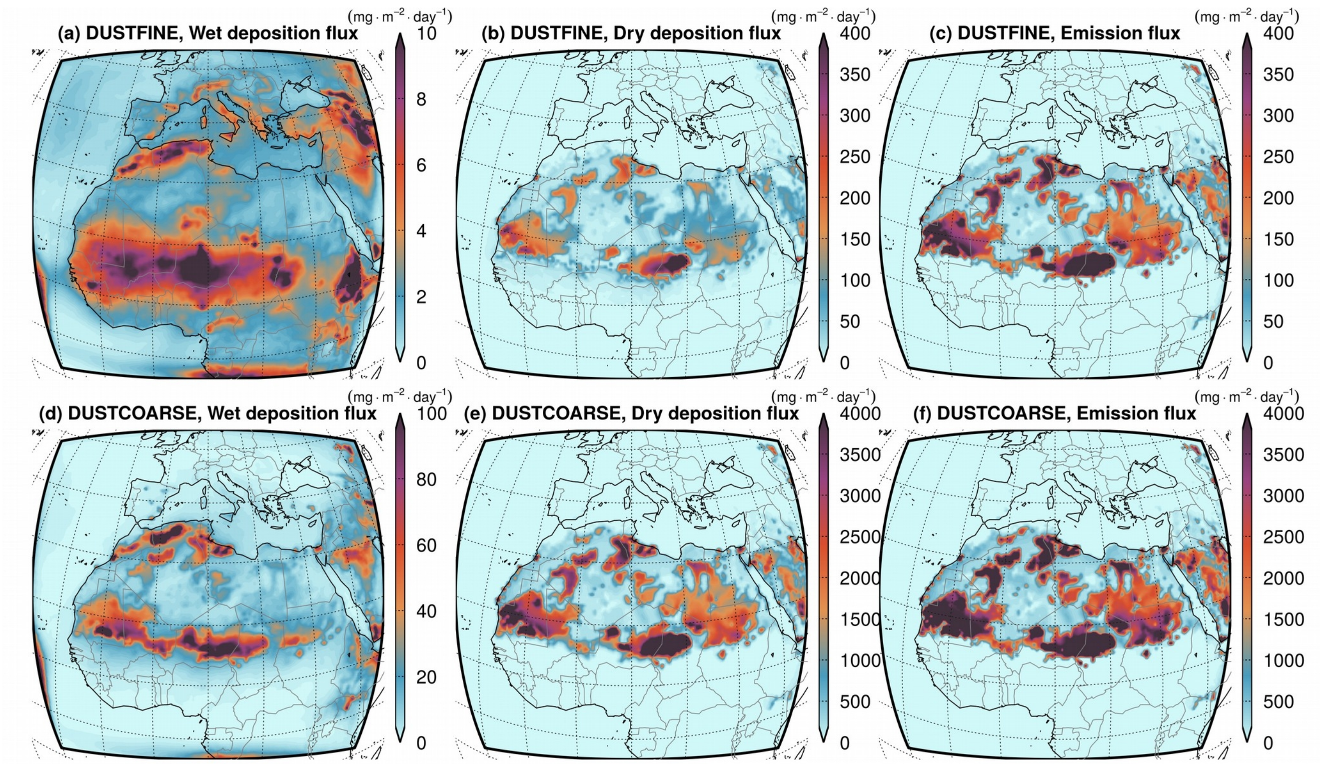
Thank you for pointing this out. Emission is incorrectly referred at this point. The two experiments have the same emission fluxes, since we are testing only the binning effect on DOD, dust column burden and RF. Therefore, we have removed emission and added DOD in the sentence.

Pg 17, Line 1-2: In the present study, we investigate the role of the modelled particle size distribution on the emission, total column burden and radiative effects of dust in a regional climate model.

Pg 18, Line 5-6: In the present study, we investigate the role of the modelled particle size distribution on DOD, ~~the emission, total~~dust column burden and radiative ~~effects~~forcing of dust in a regional climate model.

Although since the spatial distribution of emission and deposition of dust might be interesting for future readers we have included the following plot as supplementary material and cite it in the main paper:

Pg 12, lines 4-5: The spatial distribution of wet deposition, dry deposition and surface emission fluxes is depicted for the fine and coarse particles in FigureS 3.



FigureS 3: Wet deposition, dry deposition and surface emission fluxes of fine (a, b, c) and coarse (d, e, f) dust particles in DUST4 experiment for the period December 2006 to November 2014.

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7) Pg 18, line 14: The use of word ‘underestimates’ is not correct, as we have no comparison of RF figures with observation: there is no information on the reference values of the RF, so it can possibly be that the 4 bin approach is closer to the reality.

As correctly indicated the word “underestimates” may be misleading for the reader, therefore we have rephrased the sentence in order to be more comprehensive.

Pg 18, line 12-15: Overall, this study highlights that the radiative differences between the two dust size bin treatments are relatively small. The simulated shortwave radiative forcing by the 4-bin isolog method is to some extent numerically efficient and acceptable. Nevertheless, our work emphasize that the simplified representation of the 4-bin approach underestimates the direct radiative forcing, a fact that should be taking into account by future researches that study the same region.

Pg 19, line 16-19: Overall, this study highlights that the DOD, dust column burden and radiative forcing differences between the two dust size bin treatments are relatively small. The 12-bin isogradient method represents more realistically the physical processes such as deposition and optical properties of dust, nevertheless the 4-bin isolog method is numerically efficient and can be useful for long term regional climate simulations.

Acknowledgements added.

Pg 19, lines 22-31: This work is supported by the project GEO-CRADLE (Coordinating and integRating state-of-the-art Earth Observation Activities in the regions of North Africa, Middle East, and Balkans and Developing Links with GEO related initiatives towards GEOSS), Grant Agreement No. 690133, funded under European Union Horizon 2020 Programme - Topic: SC5-18b-2015, Integrating North African, Middle East and Balkan Earth Observation capacities in GEOSS. We would like also to acknowledge the support for international research staff exchange by REQUA (Regional climate-air quality interactions) project (FP7-PEOPLE-2013-IRSES - Marie Curie Action, PIRSES -GA -2013 -612671) and ACTRIS-2 project (Grand Agreement No. 654109, funded under European Union's Horizon 2020 programme). CALIPSO data were provided by NASA. LIVAS team thanks the ICARE Data and Services Center (http://www.icare.univ-lille1.fr/) for providing access to CALIPSO data used for the production of LIVAS dataset.