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Interactive comment

Interactive comment on "Evaluation of natural aerosols in CRESCENDO-ESMs: Mineral Dust" *by* Ramiro Checa-Garcia et al.

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We thank the referee for the comments and questions. They help us to improve our manuscript, in particular those aspects related to improve the readability. Here we are indicating our answers in boxed frames after each point raised by the reviewer and our changes/actions in the manuscript within a green colour box.

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Discussion paper

INFORMATION: The Table 6 has been double-checked by the different modelling groups. CNRM reported that, instead of our previous estimate, their diagnostics of dry deposition are not including sedimentation which means different values of total and dry deposition (without sedimentation). With this revision the CNRM-6DU model has a larger bias due to an unclosed budget but the CNRM-3DU decreases the previous bias by a factor 2. In this situation we have removed the model CNRM-6DU from the multi-model mean, but we kept the CNRM-3DU. Given scale of the differences between models and observations, the comparison of total deposition draws the same conclusions and the results are very similar. Because the dust emission scheme is not affected by the bias, we kept their results in the analysis. All the Tables and Figures has been revised, and several of them improved according to the new information.

In this manuscript, the authors examined the simulated dust cycle by five Earth System Models. They compared the simulated dust dry and wet depositions, dust surface concentrations, and dust optical depths against measurements across the world at both annual and seasonal scales. Their results confirmed what's known to the dust research community, including that (i) the cutoff maximum dust size is important to the dust emission magnitude, and (ii) the ratio of dry to wet depositions is highly divergent between models. Furthermore, the authors found what's less known to the dust research community, including that (i) using identical nudged winds among models can improve the consistency between models in the dust cycle, and (ii) the divergent mass extinction efficiency between models explains why similar dust loads result in a large difference in optical depth.

I agree with Anonymous Referee 1 that the presentation quality needs to be improved. The authors offered extensive and interesting results (in both the main text and the supplement). However, clear and compact leading and ending sentences per paragraph are missing. This could give readers an excuse to stop reading, and thus decrease the impact of the manuscript.

Thank you for the suggestion. We have improved the flow in several sections, in particular the section of discussion and conclusion, that now are a single new section. We have separated the recommendations to modellers about future research to be a single section because this is one of the specific objectives of the CRESCENDO project.

- Throughout the manuscript, the West Pacific and the East Pacific are defined problematically. To me, the West Pacific is the side where East Asia, Southeast Asia, and Australia are, and the East Pacific is the side where North and South Americas are located. However, the authors treated them reversely (see Fig. 1a as an example). This mismatch concerns me a lot, and can cause unnecessary misunderstandings in future studies. I suggest the authors correct the two regions throughout the manuscript systematically.

Thank you for pointing us to this nomenclature aspect.

We have changed the West vs East Pacific Ocean nomenclature across the paper: figures, tables and main text in the manuscript text.

- The cutoff maximum dust diameters of the seven models need to be better presented. First, the maximum diameters of the 4 modal models (in Table S.MD.9) are missing. Second, the maximum sizes of the 3 sectional models (Table S.MD.8) do not match Page 19 lines 10-15. For example, in Table S.MD.8, the maximum diameter of CNRM-6DU is 100 μm, however, in Page 19 line 12, the maximum diameter is 50 μm. A similar issue exists in CNRM-3DU. Since maximum diameters are critical to this manuscript, I suggest the authors address these two issues, and make the maximum diameters very clear in Section 2.

About the Page 19: There is a mismatch of values between Page 19 line 12 and Table S.MD.8 due to radius vs diameter (thank you for detecting this issue).

About the other points: In the case of models with modal aerosol particle size distributions it is not easy to unambiguously define a cut-off. Some models implement a cut-off because internally they have a sectional dust emission scheme which is mapped into a modal aerosol scheme. In these cases, it is commented in the main text when we described the dust emission scheme. Other models, like IPSL models, don't implement any kind of cut-off. They have a very low probability to find the largest particles in the tail of the log-normal distribution that, in practical terms, implies modelling or not large particles. We have clarified these aspects in the caption of Table S.MD.9. In this situation we think that might be misleading to give one single number to describe the modelling of the largest particles.

Added to manuscript: In order to resolve the important comment of the reviewer. We have added in the Table 1 additional information about the modelling of large particles. Explicitly, we have defined two classifiers:

1. If the dust scheme aims to model or not particles with diameters larger than $10\mu m$.
2. If specific separated (or mixed) modelling of particles larger than $20\mu m$ are included.

The aim is to capture better the differences of our ensemble. For example, CNRM-6DU is modelling particles up to $100\mu m$ as the last bin is covering those diameters, however with a single bin from $10\mu m$ to $100\mu m$. It is possible to argue that UKESM1 is modelling more explicitly large particles because the last bin is from $20\mu m$ to $62\mu m$ even if the upper-threshold is smaller. We think that two classifiers are more descriptive than a single number. In the case of CNRM-6DU they will be (yes, mix) and for UKESM (yes, yes).

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Discussion paper

- In Page 35 lines 8-10, the authors compared simulated deposition flux in Asia, and implicitly indicating that EC-Earth is better than all the other models. However, the tricky thing is that there is only one station in the Asian region (as seen in Fig. 1a). (Similarly, there is only one station in South Atlantic, South America, and Egypt). The sample number is too small to draw a significant conclusion for a continent. Thus, I suggest the authors make it clear that the sample number is one, and add the numbers of observational stations at all the regions in the legends of Figs. 8, 9, and 13.

We agree with the reviewer in this aspect. We have commented about the low number of measurements in several regions of the Earth. In the paragraph of Page 35, we mentioned *Asia station* to refer to a single station but not the whole region. We used the term "Asia" because it might be more easy for the reader to follow the location of the station. But we agree that this can lead to misunderstandings.

We have replaced the *Asia station* by *Asia single station*. We have done the same for South Atlantic station.

- Recent progress in dust shape and its impact on dry deposition needs to be added in Page 7 lines 16-26. Jasper Kok's group has a recent paper (Huang et al., 2020) that compiled 27 measurements of realistic dust shape worldwide (including Li and Osada, 2007). They find that dust asphericity increases gravitational settling lifetime by 20% all sizes.

Thank you for the references. They are very relevant for our discussion.

We have added these references, and we have discussed this important point.

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Discussion paper

- Recent progress in dust cycle needs to be added. A recent paper (Kok et al., 2020) that diagnosed the dust cycle is very similar to this manuscript, but used different models.

Thank you for the reference.

We have included a new paragraph it in the discussion and conclusion section: The range of dust loadings that we obtained is smaller than recent estimations Kok et al. (2021) that propose values $\gtrsim$ 20 Tg with a multi-model comparison with models with geometric diameters up to 20μm but based on a new methodology where the dust diagnostics are including observational constraints Kok et al. (2020). Actually, Adebiyi and Kok (2020) propose that the total load of dust in the atmosphere is higher than what is estimated typically, and give a mean value close to 30 Tg, where the contribution of coarse mode is more important than the fine mode.

1 Minor comments

- Typo in Page 6 line 33: correct "clay/silk" to "clay/silt"

  Corrected. Thank you.

- Typo in Table 3: the unit of grid cell area should be m^2 instead of kg

  Corrected. Thank you.

- Typo in Page 12 line 7: correct "19 stations" to "18 stations"

  Corrected. Thank you.

- Table 7 only offers emissions of 14 of the 16 regions. Regions "Mid-Atlantic" and "Sahel/Gulf of Guinea" are missing and should be added. Note that after adding the two regions, authors need to update the order of the top 10 regions with dust emission intensity.

  Thank you for this comment. We agree that a clarification is needed. It has been a typographical error from our side to name the region as "Sahel/Gulf of Guinea" as the top latitude for this region is 9N. Therefore the region is not covering the Sahel which would begin at 10N. Both regions, Gulf of Guinea and Mid-Atlantic don't have an important role in emissions, so we initially excluded them from the table.

  We have improved the text with:

  - The emissions from Gulf of Guinea have been added to the table (they don't change at all any of the results either the order or the analysis).
  - The order of the regions by emissions has been double-checked.
  - The values of Mid-Atlantic are zero as it is not including dust sources (only ocean). We added a note in the Table.

- Typos exist in Table 7's order of the top 10 regions. For instance, for EC-Earth, there are two 4th largest sources (i.e., the North Sahara and the Taklamakan), which are clearly problematic. Typos also exist in models CNRM-3DU and IPSL.

  Thank you. We have introduced some errors when reformatting the table for final submission. We have now revised and corrected the Table 7.

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