Chemical aging of atmospheric mineral dust during transatlantic transport

Reply to Anonymous Referee #2 (doi:10.5194/acp-2016-470-RC2)

by Mohamed Abdelkader and Swen Metzger, et al.,

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We thank the anonymous referee for comments on this manuscript. The comments and questions raised are addressed below by our point-by-point reply (black) and the revised MS.

General comments

This work describes the effects of chemical aging, emissions and convection parameterizations in the transport of desert dust over the Atlantic Ocean with the use of the atmospheric chemistry general circulation model EMAC. The authors have published the concept of dust chemical aging in a recent paper and in this new publication they deal with the transatlantic transport and how it can be affected by various model parameterizations related to the dust cycle. Modeling the desert dust cycle is a complicated topic given the necessity to parameterize physical processes that produce and cycle dust particles throughout the atmosphere and a better understanding of how to improve these processes is significant.

We thank the referee for this general comment.

I found the paper difficult to read, in terms of the flow, especially because there is a continuous description of the figures instead of using them to support a conclusion or remark. The main review comments are related to clarifications in the methodology and discussion of the results. I am in favor of publishing this paper with Atmospheric Chemistry and Physics with Major Revisions. The specific comments that follow will help improve the discussion of the methodology and significance of the findings so that the overall quality of the manuscript is enhanced.

We also appreciate the specific comments.

Specific comments/suggestions.

1. Please refer to aging of dust as "chemical aging" in all parts of the manuscript.

Changed "aging" to "chemical aging" throughout the manuscript.

2. Introduction, page 2, line 34: in the sentence "mean normalized bias of the AOD model varies", the word "model" should be omitted.

The word "model" is omitted.

3. Please provide the specific modules used in the EMAC configuration so that the results from this work can be reproducible.

Table 1 is included which shows the EMAC submodels used in the study.

4. Are indirect aerosol-cloud interactions included in the model configuration, besides the radiative feedback effect? How different the results might have been if these interactions were included?

Yes, through changes in the scavenging efficiency, but not through changes in CCN activity. The impact of the latter does not alter our results, since we have focused on the chemical aging of a major dust outflow between 2000 and 2013 (i.e., July 2009). For such a case, the chemical aging as represented here (various effects of changes in the wet radius) dominates the aerosol-cloud-radiation coupling. Nevertheless, the topic deserves further investigations and will be subject of a follow-up study, which then will focus on the chemical aging of weaker dust-outflow events.

5. Page 3, line 23: what is the meaning of "increases the level of dust aging"? Is there a specification of levels of chemical aging that the authors consider? I am assuming that inorganic acids uptake by the dust particles is what differentiates freshly emitted dust with dust being transported in the atmosphere, which eventually leads to "chemical aging" since the original dust particle has an altered chemical signature. Unless water uptake is considered the primary aging process. Please clarify.

We have changed this sentence to:
"This increases the dust particle mass, particle size and the removal rates, which tends to decrease the lifetime of chemically aged dust."

6. Following the same notion as in comment #4, Figure 1 indicates that insoluble emitted dust turns into aged-dust, followed by acid condensation. I would expect the acid condensation first and then the dust characterized as aged. Based on this schematic, there is no clear distinction about when dust is termed aged or non-aged.

Indeed. Figure 1 has been revised accordingly.

7. Page 3, line 27: "the mineral cations are used as reactivity proxy for natural aerosols, such as [. . .] mineral dust". Knowing how difficult it is to include chemical speciation of the emitted dust particles in the model, my question is how the authors apportioned the dust emitted mass to mineral cations. Is it a fixed percentage for calcium, magnesium and potassium? This information must be made clear in the text.

Yes, we follow Abdelkader et al. (2015) and use a fixed percentage for this study. This percentage has been determined in order to best match the observations of various mineral cations from EMEP and CASTNET observations. A more comprehensive treatment is under development.

8. Sections 3 and 4: as mentioned in the beginning, in a lot of parts of the discussion there is a description of the figure instead of a narrative about the main findings, followed and supported by the figures. I strongly encourage the authors to revise parts of the text accordingly, which will greatly benefit the quality of the manuscript.

Both parts have been revised.

9. What is the basis for the selection of the six specific stations that were included in the sensitivity tests, out of the ones shown in Fig. 4? It seems from fig.4 that more stations were available inside the specific zones.

Figure 4 includes the stations that have data for a longterm evaluation (2000-2012), while only the selected stations have observations for the selected period (July 2009).

10. Page 6, line 9: is the 600ug/m3 an observed or simulated value for dust concentration?. The values refers to the model. We have added "modeled surface concentration" for clarification.

11. Page 7, lines 2-3: the aging of dust particles throughout the transatlantic transport depends also on the availability of inorganic acids in this region. The EMAC model outputs corroborate with the assumption that inorganic acids can be found in the DTA and/or DIZ zone?

Yes. The inorganic aerosol precursor gases (HCl, HNO_3, H_2SO_4) are ubiquitous, as we consider in our EMAC study various processes and anthropogenic (e.g., ships and flight traffic) and natural sources (e.g., lighting, chlorine activation of sea spray due condensation of e.g., HNO_3, H_2SO_4).

12. Table 1: I believe rm and ro are supposed to be standard deviations sigmam and sigmao. Please revise accordingly.

r_m and r_o are the geometric mean of the model and observations, respectively. We have added a description of the statistical parameters in the Appendix A.

13. Table 1: what is GFE, PF2 and PF10? They are not included in the appendix and never mentioned in the text.

GFE denotes the Growth Factorial Error, while PF2 the Fractions of points within a factor of two from the observations; accordingly, PF10, the points within a fraction of 10 from the observations. The definitions have been added to the description in Appendix A.

14. Figure 10, caption: please include the time period that the plots cover. Also, remind the reader which plots correspond to the ECMWF and TIEDTKE schemes.

The time period is now included in the figure captions.

15. Figure 11: is the standard deviation of the TRMM product calculated over the meridional mean to show the variation/dispersion of the precipitation at each longitude? Why not show the stdev for the model outputs as well?

Yes. The standard deviation of the model results has been included in Figure 11.

16. Are Figures 10 and 11 for the same time period, July 2009? If so, the meridional means are confusing. They show that B1T5 is closer to the observations but Figure 10 indicates that maybe EMAC base case is closer to TRMM.

Yes, both figures show monthly averages for July 2009. But, comparing Figure 10 and 11 is somewhat deceptive, since Figure 10 represents a qualitative comparison of the spatial distribu-

tion of precipitation and the extent of the dust plume, while Figure 11 represents a quantitate comparison, which generally is more accurate. And from Figure 11 the simulation B1T5 is closer to the observations, at least for 90-50W, while the opposite is only true for the region of 20-10W.

17. Figures 13 and 14 show monthly means for July 2009?

Yes, this is now noted in the figure caption.

18. The paper title in the supplement is not correct. Please revise accordingly.

Both changed, according to the comment of reviewer one to:
"Sensitivity of transatlantic dust transport to chemical aging and related atmospheric processes".

19. In the conclusions section, there is discussion on the findings from the sensitivity tests and model evaluation. A general conclusion about the new and significant findings from this work is necessary and, perhaps, a recommendation to the model users about the choices that would produce more reliable mineral dust simulations.

A general conclusion and a recommendation has been added to the conclusions section.

References

Abdelkader, M., Metzger, S., Mamouri, R. E., Astitha, M., Barrie, L., Levin, Z., and Lelieveld, J.: Dust–air pollution dynamics over the eastern Mediterranean, Atmospheric Chemistry and Physics, 15, 9173–9189, doi:10.5194/acp-15-9173-2015, URL `http://www.atmos-chem-phys.net/15/9173/2015/`, 2015.