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Atmospheric Chemistry and Physics Discussions

Interactive comment on "On realistic size equivalence and shape of spheroidal Saharan mineral dust particles applied in solar and thermal radiative transfer calculations" *by* S. Otto et al.

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Dear Mr. Gasteiger!

You wrote that 'this in an interesting and useful study which deserves publication in ACP.' Thank you very much for your encouragement. Then you listed some potential sources of uncertainty w.r.t. to the results. I would like to comment all these points. Your statements are indicated in bold letters.

1) **Method for derivation of vertical profile of number concentration (I believe, a brief outline of the main steps of this method would improve the paper).**
The derivation is explained in Otto et al. (2009) at the beginning of Section 5. Therefore, I would like to avoid to 'copy' the respective text to the new paper. However, if the editor wishes an additional explanation in the main text, I will do it, of course. For the moment, I will give a short description to the derivation of the profile: As you know Dr. B. Weinzierl/Dr. A. Petzold performed the particle measurements onboard the Falcon applying a variety of instruments. They measured accumulation and coarse mode number concentrations during each flight. At constant flight legs, that is, at constant altitude levels, they carried out the size distribution measurements, two on 19 May 2006 which I considered. But the information about the concentration at two different levels are not sufficient to calculate the vertical extinction coefficient/optical depth, e.g., to be compared with the lidar results. To get the vertical information I took the flight data of the number concentration. Unfortunately, only the accumulation mode data were available. Another problem was that each measured value corresponds to a certain altitude during the flight. That means, only by considering a sufficiently large time interval (10:50-12:20, see Section 5 in Otto et al., 2009, or the new paper on page 29208, line 7) the aircraft covered the entire altitude range. Fortunately, the aircraft was flown through some altitude ranges inside the dusty atmosphere twice or more times which provided better statistics. Of course, the time span of more than one hour is a source of uncertainty to derive a vertical profile of the accumulation mode concentration, however, otherwise *no* vertical information would have been available. The numerical process of deriving the profile is very simple: Define a high-resolved altitude grid, relate the measured concentrations to the corresponding grid point and average vertically to smooth out the roughness in the data (Otto et al., 2009).
However, the accumulation mode profile is also not sufficient because the total number concentration is required. I hence calculated the accumulation mode concentration at the two altitude levels of the size distribution measurements based on the derived modal parameters. Compared to the total number concentrations a factor of approxi-

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mately the same value of 2.5 was obtained at both levels by which the total exceeded the accumulation mode concentration. I then applied this factor to all altitudes and calculated the profile of the total concentration from the accumulation mode profile. Of course, this is a source of uncertainty, but I see no other way to derive a more realistic and/or more exact profile. On the other hand, the dust plumes were observed to be very spatio-temporally homogeneous during SAMUM-1 (see Weinzierl et al., 2009, and as stated by other field scientists and SAMUM-1 papers) and the extinction coefficient and optical depth profiles derived from my number concentration profile fitted very well to the lidar measurements (Otto et al., 2009).

2) **Spatial and temporal averaging of the number concentration profile used as model input. At the beginning of Sect. 5 of Otto et al. (2009), the authors describe that the vertical profile is averaged from 10:50 UTC to 12:20 UTC. As data from aircraft is used, spatial averaging implicitly took place, also. I would except a some percent uncertainty for the modeled AOD from this averaging. E.g., the shapes of the vertical profiles in Fig. 9 are not exactly the same for model results and lidar measurements.**
As explained in 1), of course, there is an uncertainty due to the temporal averaging, which means a spatial (horizontal and vertical) smoothing. But I see no way to avoid it. The aircraft cannot fly exactly in vertical direction to get vertical information in a 'small' column, e.g., above the ground stations during SAMUM-1. I also would expect some uncertainty, however, how to estimate that? The exact 3D structure of the dust plume is not known. Otherwise no averging like this would be needed.
The differences in the shapes of the vertical profiles in Fig. 9 were not the result of the temporal (spatial) averaging, but the result of the size distribution measurements (modal parameters), whose application in the calculation of the extinction led to an overestimation of about 10 % for only the upper measurement level (personal communication to Dr. B. Weinzierl). One also has to keep in mind that both the particle and the lidar measurements involve a certain temporal (spatial) averaging. Compare

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the two lidar profiles in the same figure. They only agree at about 4 km altitude, which might be coincidental.

3) **Is there any aerosol modeled above 5.6 km asl? If not, an aerosol optical depth in the order of 0.01 might be missing in the model.**
There is no aerosol above the 5.6 km in the model. This is just traced back to the fact that there were no experimental information availabe w.r.t. this point.

4) **Size distributions.**
Of course, they have some uncertainties. In Weinzierl et al. (2009) a detailed discussion of the uncertainties is not given. I am a modeller and just applied the modal parameter data from the field scientist. I know that the authors of Weinzierl's paper are experts in the field of particle measurement and, to the best of my knowlegde, one can assume that they determined their data overcarefully.

5) **Model shapes.**
Of course, real particles are not of spherical shape. They are also not of spheroidal shape in the sense that they exactly fit the continuous surface of a model spheroid without any edges. I know that. But in order to determine the uncertainties in the optical properties due to the shape one has to know the exact shape of each particle. This will never be possible to find out. On the other hand one has to be able to compute the single scattering properties for all these particles of different sizes, especially, large particles with size parameters much larger than 20 are very important. As I know there is no code available to compute those of irregularly-shaped (beyond spheroids) particles exactly above this approximate value of 20. Most codes numerically fail or do not converge as you know. Thus, one has to go back to simpler shapes as spheroids for large and very large size parameters, as you know. This is a numerical limitation which cannot be avoided at the moment. In this context, I am just very happy to be able to consider the entire size range of the spheroidal model particles at all.

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6) **Aerosol optical depth from Sun photometer.**
Yes, this is another source of uncertainty which is given in Table 1.

7) **Combining all these uncertainties likely results in an uncertainty of notably more than 8 % for the aerosol optical depth. In this case, the size definitions VSEQV, VEQV, and SEQV are equally valid and a statement like the above-mentioned in the abstract is not useful. The paper would benefit from the consideration of the uncertainties (at least rough estimates of them should be possible).**
Of course, you are right that uncertainties may lead to values of the optical depth different to the modelled ones which are reported for the considered situation on 19 May 2006 during SAMUM-1. But this is what is already meant at the beginning of page 29209 by 'With regard to uncertainties in optical depth measurements and the relatively small deviations between the cases VEQV, SEQV and VSEQV for prolate shape, the lidar data together with the more realistic consideration of AR distributions enables us to state that *at least* prolate shape is rather realistic than oblate.' This obviously means that actually only the shape is constrained and that VEQV, SEQV and VSEQV are all candidates for realistic size equivalence. However, to the best of my knowledge I tried to select the best one based on all available data. Moreover, keeping in mind the above-mentioned uncertainties I performed all radiative transfer simulations for both VEQV, SEQV and VSEQV (and LAEQV and SAEQV) later in the paper. This was also done in order to demonstrate that the size equivalence is an important parameter when dealing with non-spherical particles.
I also wish to note that I already stated with regard to the uncertainties of the particle shape on page 29902 and line 9-13 that 'This demonstrates explicitly the ambiguities w.r.t. free variables when ensemble optical property calculations involve the treatment of non-spherical particles and that particle models beyond the simple spheroid approximation may lead to differing results.' This underlines the importance of the considered

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shape and that another shape may, of course, lead to differing interpretations of the results.

Finally I also would like refer to your '**hope [to] consider this comment which is related to the conclusion 'volume-to-surface equivalent spheroids [...] are most realistic' (line 7-8 of the abstract).**' Again, I applied the SAMUM-1 data to the best of my knowlegde to constrain the independent parameters, particle shape and size equivalence, by treating the dust particles to be spheroidal. Thus, the results refer to spheroidal model particles only. The title 'On realistic size equivalence and shape of spheroidal Saharan mineral dust particles applied in solar and thermal radiative transfer calculations' expresses this explicitly. If you wishes to consider other particles shapes, you might get differing results w.r.t. shape and size equivalence. I hope that you will keep in mind the importance of the latter quantity when interpreting the particle data in your investigations. This is one of the most important results of our study.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 29191, 2010.