

***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.***

**S. Otto et al.**

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Dear Reviewer 1!

You stated that **'This is a thorough and instructive theoretical study of the effects of nonsphericity of dust aerosols on their integral radiative properties. This study is original and useful and deserves publication after a minor revision.'** Thank you very much for these nice words.

We would like to consider your comments which are written in bold letters in the following.

1) **Page 29198, line 20. This sounds like the authors have developed their own versions of the NF and GOA methods. If so, they should provide a few details to make the paper more self-contained. If not, references to original papers should be given.**

No, we did not develop our own version. The citation '(Otto et al., 2009)' in lines 20-21 should mean that one has to study that paper and the works cited therein for detailed information about the used codes. To avoid confusions we would like to change the text as follows: 'Scattering database for single (homogeneous and orientation-averaged) spheroidal particles extended by exact null-field (NF) method in the transition region of this method and geometrical optics approximation (GOA) methods (for details to the codes applied see Otto et al., 2009, and the corresponding works cited therein), that is, for volume-equivalent size parameters between 50 and 100; Interface to a second scattering database (Schmidt et al., 2009) based on an independent NF code.' We also can cite the papers of Mishchenko, Yang, Macke et al. as done by Otto et al. (2009).

2) **Laboratory measurements by Volten and Munoz (several JGR, JQSRT, and Astron. Astrophys. papers) give us a pretty good idea of how the phase functions for natural dust particles should look like. It would be instructive to see plots of the theoretical phase functions in order to conclude whether the modeling results reported in this paper are plausible.**

In the attached Fig. 1 our phase functions (normalised to 1 at  $30^\circ$  scattering angle) are shown for 632.8 nm and at an altitude at the centre of the observed dust plume (3375 m asl), that is, for spherical particles (orange) and spheroidal particles of prolate shape averaged over the axis ratio distribution (ARD) as shown in Fig. 1 of our paper and assuming volume-to-surface equivalence. The red curve means the consideration of the entire size distribution and the green one that case in which all particles larger than 3 micrometers in diameter are neglected. In comparison to the measurements

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of Volten et al. (black symbols) we see that our spheroidal phase functions are within the range of typical functions obtained by measurements. They clearly differ in shape from the according phase function of spheres. As expected particle size does change the shape of the normalised phase function in forward direction only.

We also would like to note that aerosols are highly variable w.r.t. their chemical composition. The dust on which Volten's measurements were based may differ to that dust observed during SAMUM-1. Moreover, experimental conditions may also be different from in-situ situations.

**3. The authors focus on the integral radiative properties, whereas Mishchenko et al. (GRL, 1995) and Dubovik et al. (JGR, 2006) claim that nonsphericity has a much stronger effect on remote sensing via profound modifications of the elements of the scattering matrix. The authors should comment on the remote-sensing implications of their modeling of the optical properties of nonspherical dust particles.**

We did not investigate scattering matrices, we only concentrated on scalar optical properties and scalar one-dimensional radiative transfer with regard to energetic effects of the dust. Moreover, one of our main goals is to point out the role of the particle shape and the size equivalence assumption when interpreting the measured size distributions. This is implicitly important for retrievals dealing with size information inside the algorithm because one always has to interpret the term 'size' in a realistic way. In this sense we stress that size equivalence and particle shape are two independent parameters which has to be considered separately in the retrieval. This complicates the situations, of course.

Another important fact we stress is the role of the large particles which are hard to retrieve as the results of AERONET (Dubovik et al., 2006) demonstrate in the case of Saharan mineral dust. This leads to inconsistencies in the optical properties (single scattering albedo and asymmetry parameter) in comparison to the experimental results of SAMUM-1.

We also wish to note that size equivalence comes into play not only within the scope of size distribution interpretation. It is also important for the interpretation of the chemical composition (and hence for complex refractive index retrieval) as a function of particle size. Thus, one actually could assume different size equivalence cases for size distribution and composition data (we assumed the same size equivalence for both data types). Furthermore, size equivalence could also vary independently over the size range of size distribution and composition data according to different measurement techniques. This underlines the complexity involved in the treatment of non-spherical particles with regard to the property 'size equivalence' in aerosol retrievals.

The implications are noted, e.g., on page 29218 (lines 9-11) by 'Beyond, the consideration and quantification of the particle shape and optical size equivalence within the scope of the particle size measurements are important for accurately modelling the radiative impact of aerosols and clouds.' that size measurements (this also holds for composition measurements as a function of particle size) should provide information about the size equivalence to simulate dust optical properties and (forward) radiative transfer more exactly. With regard to dust retrievals we state on page 29206 (lines 21-23) that 'This ambiguity might be one reason for difficulties in simultaneous derivation of imaginary part and coarse mode fraction by recent dust retrievals (Müller et al., 2010).' Especially, Müller et al. (2010) summarised some inconsistencies of retrieval and in-situ modelling results. A more detailed paper on such 'remote-sensing implications' is already in preparation to which we would like put off the reviewer for the moment (as also stated by Reviewer 2).

We also discuss 'remote-sensing implications' on page 29211 (lines 24-26) by 'Thus, subject to the sensitivities found above, non-sphericity information might be retrieved by ground-based radiometric measurements over land but rather by satellite-based observations over ocean if the measurement accuracy is sufficient for both strategies.' based on our irradiance simulations. A second is given on page 29219 (lines 10-15) by 'Radiative transfer quantities may not be bijective functions of certain free parameters,

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e.g., the micro-physical properties of aerosol particles. This fact may be problematic vice versa when deriving, e.g., micro-physical aerosol properties from standard radiometric or lidar measurements (inversion). The consideration of polarimetric data in inversions dealing with polarisation and accounting for particle non-sphericity might be a promising approach to minimise uncertainties in aerosol remote sensing techniques.' indicating the non-uniqueness of the retrieval problem and stressing the application of polarisation-based measurements, ground- and/or satellite-based. Third, we conclude on page 29207 (lines 15-17) that 'These discrepancies demonstrate that further efforts have to be made in developing improved aerosol retrieval algorithms. Furthermore, the exploitation of passive polarimetric measurements may provide valuable information.', and on page 29211/2 (lines 29-3) that 'Compared to our computations such a measurement accuracy is not sufficient for constraining particle non-sphericity of mineral dust particles compared to simulations. The consideration of radiances or polarimetric measurements might be more promising, since larger sensitivities may be expected (Li et al., 2007).' Finally, we point out in the Conclusions that 'Radiative transfer quantities may not be bijective functions of certain free parameters, e.g., the micro-physical properties of aerosol particles. This fact may be problematic vice versa when deriving, e.g., micro-physical aerosol properties from standard radiometric or lidar measurements (inversion). The consideration of polarimetric data in inversions dealing with polarisation and accounting for particle non-sphericity might be a promising approach to minimise uncertainties in aerosol remote sensing techniques.' Thus, we believe that 'remote-sensing implications' are already discussed qualitatively. A quantitative study is in preparation.

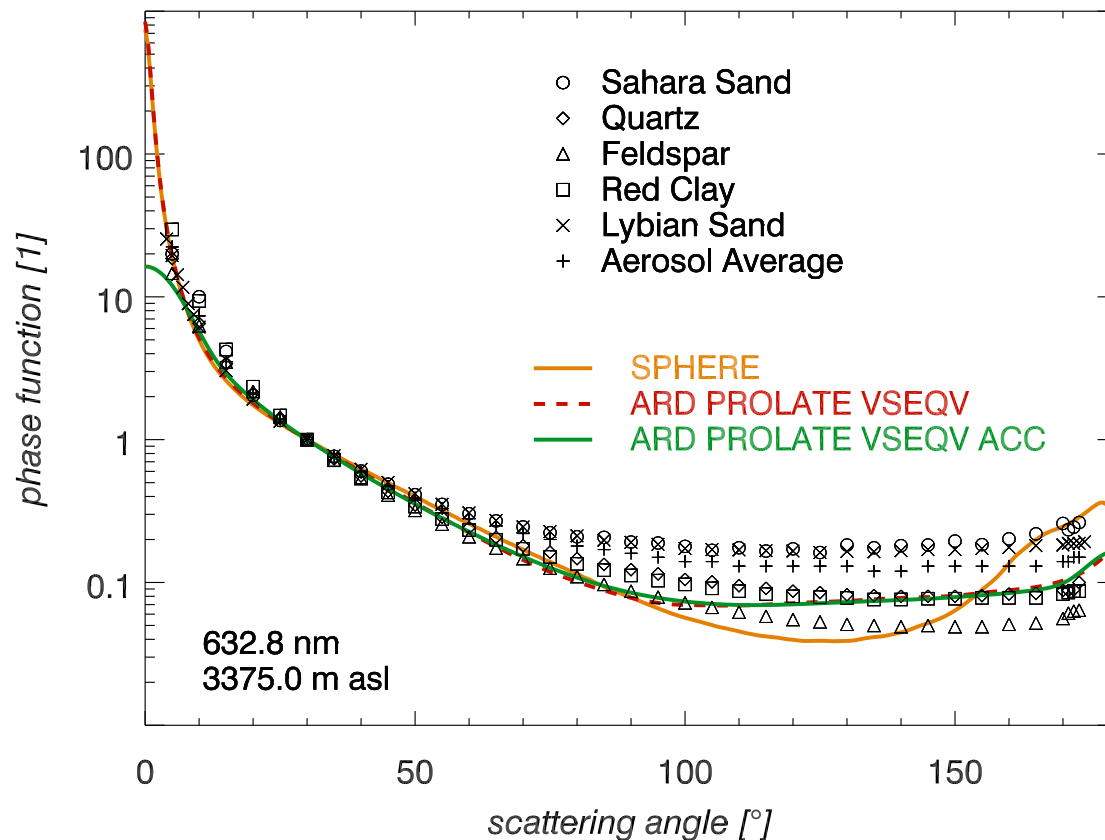
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**Fig. 1.** Phase functions of Saharan dust observed during SAMUM-1 assuming spherical and spheroidal particles compared to phase functions of mineral aerosols measured by Volten and others. See text for details.

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