**Atmospheric
Chemistry
and Physics
Discussions**

Interactive comment on "Modelling light scattering by mineral dust using spheroids: assessment of applicability" *by* S. Merikallio et al.

Anonymous Referee #1

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General Comments

Good knowledge of the light scattering behavior of irregular dust particles is mandatory for studying their radiative impact in the atmosphere. Its theoretical study is far from trivial due to the high variety of geometries of dust particles. Moreover, they are usually distributed over broad size distributions. Therefore, new efforts in that direction are always of a great interest. In this paper, the authors present a thorough study to asses the validity of the spheroidal model for simulating the scattering behavior of irregular dust particles. Moreover, they study whether a generic shape distribution of spheroids can be applied to a broad range of dust samples candidate to be in the Earth atmosphere. To do that, calculations are compared to experimental scattering matrices of a broad range a dust samples. Apart from the detailed description of the methodology

employed in this study, the authors give a quite critical presentation of their own results which is highly laudable. Therefore, I strongly recommend publication of this paper on Atmospheric Chemistry and Physics. However, there are some minor issues that I would like the authors to clarify before publication.

Specific Comments

1. Section 3, "Measurements", paragraph 145: In my opinion the way Mueller/phase/scattering matrix are defined in Sections 2 and 3 is a bit confusing. By definition, a Mueller matrix is a $4{\times}4$ matrix that describes each linear change of a column Stokes vector into a similar column Stokes vector (see e.g. Transfer of Polarized light in Planetary atmospheres, Hovenier, Van der Mee, Domke; 2004). As such, any of the matrices presented in the paper can be called Mueller matrices. The phase matrix relates the Stokes parameters of the incident and scattered beams, defined relative to their respective meridional planes. In contrast, the scattering matrix relates the Stokes parameters of the incident and scattered beams defined with respect to the scattering plane (See e.g. "Light scattering by nonspherical particles", Mishchenko, Hovenier, Travis, 2000; "Transfer of Polarized light in Planetary atmospheres", Hovenier, Van der Mee, Domke; 2004). According to that, F and P are both scattering matrices but with different normalizations. If the authors are following different definitions they should specify the sources.

2. Section 3, paragraph 150 and Section 4 paragraph 160: Do the computations cover the complete size distribution of all five samples?

3. Section 4.1, paragraph 225: *'It is interesting to note that all the other scattering-matrix elements show strong dependence on size except for P_{12}/P_{11} and P_{34}/P_{11}, which are reproduced quite well with spheroids regardless of the size range.'*

It is also interesting that those two element ratios do not seem to depend that much on the refractive index used in the calculations. On the contrary the P_{11} element seem to be quite dependent on the refractive index in all studied cases.

4. Section 4.3, paragraph 285: *"Curiously, unlike P_{11}, the best-fit n for the asymmetry parameter g is slightly larger. This may be because the calculation of the asymmetry parameter takes into account also the extrapolated diffraction peak".*

In principle the forward diffraction peak is not that sensitive to the shape of the particles but on the size distribution. Indeed, that is the assumption used for the extrapolation of the phase function at small scattering angles (Liu et al. 2003; Kahnert and Nousiainen 2006; Kahnert and Nousiainen 2007). If for getting a good-fit for g we need a higher value of n it seems like the diffraction forward peak could be shape-sensitive. Can you comment on that or could you think of any other reasons for the requested values of n for the best-fit of g?

5. Section 4.3, paragraph 290: Although the HSA (Homogeneous Sphere Approximation) is defined on page 2, it would facilitate the reading if the definition is included again on page 9. There are a lot of information and definitions of variables in the previous pages and it is difficult to retain all of them specially when it was given 7 pages earlier.

6. Section 4.4, paragraph 360, The authors mention the results for loess but they are not shown in Figure 5. That should be mentioned in the text.

7. Section 5, paragraph 435, *"When the asymmetry parameter is the criterion, a reasonable first assumption for a spheroid shape distribution is to use the power law function with n=3. For P_{11} element, the equiprobable distribution often works the best, whilst for the polarisation elements it might prove profitable to favour heavily the most extreme shapes (n=18)."*

According to Figure 6, the asymmetry parameter as well as the F_{11}, and F_{12} elements (except in the Sahara case) are reasonably well reproduced with the power law distribution with n=3 and n=10 with very small differences between each other. I do not see that in any of the studied cases, the equiprobable distribution is the best option for the F_{11} element. Moreover, you write "Pij" in the text but F_{ij} in the figure. Please, correct

C134

that. I assume that in all plots when you say P_{11} you mean that they are normalized according to equation (2). If that is not the case you should mention which normalization is used and they should not be called P_{11}.

8. Section 5, paragraph 440: What do you mean with a "generic size distribution"? Do you mean a generic **shape distribution**?

9. Section 6, paragraph 495 *"It turns out that it is impossible to suggest a single shape distribution that would be the best choice in all cases. Not only does the best-fit distribution vary between the samples, but it also varies between the wavelengths, the metrics used for specifying the goodness of fit, the quantities fitted, and the refractive index assumed."*

In my opinion this is a too strong/negative statement. It is clear that the P_{22} element is not well reproduced by any of the studied shape distributions. Thus, the spheroidal model does not seem to be a good model for studding depolarization properties of dust particles. However, it seems like the shape distributions with n=3 and n=10 are in general a good approximation for all studied samples specially if we focus on the asymmetry parameter, and the F_{11} and F_{12}/F_{11} elements (see point 7 of this review). The fits can be further improved by using n=18. Moreover, it is clear that even when the fits are not perfect, a shape distribution of spheroids (for samples with relatively small r_{eff}) is a better approximation by far (including the F_{22}/F_{11} ratio!) than the Homogeneous Spherical Approximation.Therefore, I recommend to reformulate the paragraph.

Apart from that, in this paper the chosen set of samples correspond to a quite broad scenario attending to their origin. However, it seems like the scattering behavior of different dust samples is confined to rather limited domains when they are grouped according to their origin (see e.g. Munoz et al. JGR, 109, D16201, doi:10.1029/2004JD004684). That seems to be in agreement with the results presented in this paper for red and green clay. I would recommend as a future work to perform a similar study on several different groups of samples like e.g. clays, volcanic

C135

ashes, or desert dust. That would probably facilitate the definition of a single shape distribution representative for each of the groups. That can provide a powerful diagnostic tool for irregular aerosols in the atmosphere.