Comment on amt-2022-27

Anonymous Referee #1

Referee comment on "The polarimetric characteristics of dust with irregular shapes: evaluation of the spheroid model for single particles" by Jie Luo et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2022-27-RC2, 2022

The manuscript on "The polarimetric characteristics of dust with irregular shapes: Evaluation of the spheroid model" discusses the applicability of the spheroidal shape for reproducing the scattering properties of irregularly-shaped dust particles. This is a valuable study that is long-awaited by the community, thus it is of value to be published. That being said, the study is far from providing a complete answer on the applicability of spheroids for reproducing the scattering properties of dust, and it should be clearly presented as a first step towards this direction. In this context, the following limitations have to be highlighted and discussed:

- The study presents the scattering properties of single particles. As shown in several studies in the literature, with one of the most prominent the work of Dubovik et al. (2006), in order to reproduce the scattering properties of dust, ensembles of spheroidal particles are used (i.e. with a distribution of sizes and aspect ratios) and not single spheroidal particles. Thus, differences seen in the scattering of single spheroidal particles with single irregularly-shaped particles do not necessarily indicate the inability of an ensemble of spheroidal particles to reproduce the scattering properties of an ensemble of irregularly-shaped dust particles. These differences may be viewed as a first step towards exploring the applicability of spheroidal shapes for reproducing the scattering properties of dust, and this is how it should be presented in the manuscript. This limitation should be clearly highlighted, both in the abstract and in the rest of the manuscript, but also in the title, by changing it to: "The polarimetric characteristics of dust with irregular shapes: Evaluation of the spheroid model for single particles".
- The sizes of dust particles in the study are quite limited, considering mainly the fine dust particles (i.e., radius up to 2.0 μm). This should be highlighted in the abstract.
- The radiative transfer calculations presented in the manuscript use the scattering properties of single particles (if I understood correctly). This is unrealistic for the radiative transfer calculations in the atmosphere. Thus, the radiative transfer calculations presented in the manuscript should be re-calculated, using the scattering properties of ensembles of particles (not of single particles), otherwise this part (i.e. Sect. 2.4 and 3.2) should be omitted.
- The quantification of the differences in the scattering properties of single spheroidal particles and single irregularly-shaped particles, is not thoroughly provided in the

manuscript. Be specific and provide numbers.
- As mentioned in the technical review, the use of English language in the manuscript is not optimum, and it should be thoroughly revised, especially for Sect. 1 (Introduction).

General comments:

- Include in the abstract the limitations discussed in comments (1), (2) and (3) above.

More specific comments:

Line 9 "… substantial deviations…": Provide quantification.

Line 9 "…. is relatively large.": Provide the size (and size parameter) range used.

Lines 14-15 "The deviations of the spheroid model… (VRT) model": Re-calculate the RT using ensembles of particles, or exclude this (see comment (3) above).

Lines 20-21 "Thus, the use… dust shapes.": Rephrase this, based on comment (1) above.

Lines 35-38 "However… of the surface": Rephrase (not optimum use of English). Also, the satellite aerosol retrieval algorithms do not only suffer from the "perturbs of the surface". Discuss and provide references.

Lines 39-40 "The polarization… Li et al., 2016": Rephrase (not optimum use of English).

Line 47 "However, … calculations,": Substitute it with "However, the full calculations require to use the vector radiative transfer,"

Line 48 "In most remote sensing algorithms…": Start a new paragraph.

Line 52 "Dust particles… 2011).": Delete this sentence.

Line 53 "The spheroid model…": Do not start a new paragraph here.

Line 54 "(Dubovik et al., 2006; 2011)": Substitute it with "(e.g., Dubovik et al., 2006)".

Line 54 "Compared … determined": Substitute it with "Compared to the spherical model, the aspect ratio of the particle needs to be determined.".

Lines 54-55 "The retrieval… 2011).": Delete this sentence.

Lines 58-68: Re-write the whole paragraph, based on the following: a) Spheroids are used as a model for reproducing the optical properties of dust, thus their aspect ratio is not necessarily a microphysical property of the particles, and it is usually not retrieved. E.g. Mishchenko et al. (1997) do not retrieve the aspect ratio of the spheroids. Delete the sentence "In traditional… of spheroids." b) The phase function of dust particles is reproduced using ensembles of spheroidal particles. There is no extensive study on the ability of the ensembles of spheroids to reproduce all the elements of the scattering matrix of dust. Emphasize that the current study is a first step towards this direction, showing the reproduction of the scattering matrix of single dust particles, using single spheroidal particles.

Line 72 "…Kahnert, 2015).": Include also "Gasteiger et al., 2011" (Gasteiger, J., Wiegner, M., Groß, S., Freudenthaler, V., Toledano, C., Tesche, M., and Kandler, K.: Modelling lidar-relevant optical properties of complex mineral dust aerosols, Tellus, B 63, 725–741, doi:10.1111/j.1600-0889.2011.00559.x, 2011.).

Lines 69-78 "Some modelling works… investigated.": Re-write the whole paragraph, based on comment (1) above.

Line 83: Before this line, start a new paragraph, discussing the limitations of the current

work (see comments (1) and (2)). Describe this work as a first step towards a more complete analysis.

Line 90, Sect. 2.1: Mention (in this section) the lack of faceted particles in the analysis. See for example particles "E" and "F" in Fig. 1 in Gasteiger et al. (2011).

Lines 103-104 "…and it can simulate the roughness of the surface.": The roughness of the surface is probably at smaller scales than the dipole size. Please discuss and provide references.

Lines 113-114 "…and Vo denotes the volume lost in the erosion process. As shown in Figure 2, with a larger R, the dust shapes are easier becomes spherical due to larger binding force.": Substitute with "…and VLost denotes the volume lost in the erosion process. As shown in Figure 2, with a larger R, the dust shapes become more spherical due to the larger binding force."

Lines 118-121 "The normalized… Mishchenko et al., 2002)": Substitute with "The normalized scattering matrix, extinction cross-section (Cext), and scattering cross-section (Csca) are the key parameters of the single scattering properties of aerosols (Mishchenko et al., 2002; Liu and Mishchenko, 2005). The normalized Stokes scattering matrix has six independent elements (Paton, 1958; Mishchenko et al., 2002)".

Eq. 3: Provide the assumptions that result in this simplified form of the scattering matrix (randomly-oriented particles etc).

Line 130 "…the irregular dust particles.": Substitute with "…the irregular dust particles (Gasteiger et al., 2011)."

Lines 138-139 "…and the accuracy of the DDSCAT is acceptable.": Acceptable based on which threshold? Elaborate and discuss.

Lines 146-156: Re-do the radiative transfer calculations using the scattering properties of particle ensembles, and not of single particles (see comment (3) above). If the calculations cannot be re-done, omit Sect. 2.4.

Line 158 "3.1 Single scattering properties of dust with irregular shapes": Substitute it with "3.1 Single scattering properties of single dust particles with irregular shapes".

Line 166 "…would result in more obvious non-sphericity…": What do you mean by this sentence? Please elaborate.

Lines 170-179: Different values for R result in quite different shapes. I do not think the comparison presented in this paragraph is very helpful, since you compare almost spheres with spheroids. If you want to keep it, start the paragraph with the last two sentences "When R=0, the binding force… , so F22/F11 become more close to 1.".

Lines 183-184 "Thus, the spheroid model… for small dust": Substitute with "Thus, single spheroidal particles can provide a reasonable estimation for small single dust particles.".

Lines 185-187 "Besides, … fitted using spheroids.": Avoid making these statements. As you can see in Fig. 2 in Gasteiger et al. (2011), more irregular shapes do not necessarily show larger depolarization values (i.e., smaller F22/F11).

Lines 190-191 "The dust… those of spheroids.": This is not generally true either. See again Fig. 2 in Gasteiger et al. (2011).

Lines 191-195 "The trends… spheroids.": Please provide quantification instead of "rather similar" and "rather different".

Line 197 "With an original aspect ratio of 1:1, the spheroids…": Substitute with "With an original aspect ratio of 1:1, spheres….".

Lines 196-198: Quantify the "relative well" and "relative bad" fits.

Line 198 "The reason is that…": Substitute with "The reason may be that…".

Lines 207-208 "…the best-fitted Cext and Csca…": Do they correspond to the spheroids that best-fit the phase function? Make this more clear.

Line 210 "…turns obvious…": Substitute with "…increases…".

Line 212 "…would constraining…": Substitute with "…constrains…".

Line 213 "…and the retrieved aspect ratio is more close to 1:1.": Not only the retrieved but also the actual aspect ratio. Correct the sentence accordingly.

Table 2: Correct the "Aspect Ration" in the header, with "Aspect Ratio".

Section 3.2: Re-calculate the radiative transfer using ensembles of particles, otherwise omit this section (see comment (3) above).

Lines 304-307 "The spheroid model… of complex dust, …": Substitute with "The spheroidal shapes are commonly used to reproduce the scattering properties of dust, while their applicability is still unclear. To calculate the scattering properties of dust, ….".

Lines 312-314 "… of dust with different shapes…. were compared.": Substitute with "of dust with different shapes (but not for faceted dust particles). To evaluate the capability of spheroids to reproduce the single dust particle scattering properties, we used single spheroidal particles that fit well the phase function of single dust particles with irregular shapes, and then we investigated their capability to reproduce all the elements of the scattering matrix.".

Line 315 "The single… investigated.": Substitute with "The single scattering properties of single dust particles with irregular shapes were investigated.".

Line 318 "…insensitive.": Substitute with "…small." and provide quantification.

Line 323 "Besides, the sign…": Substitute with "The sign…".

Line 329 "…. close to 1:1.": Substitute with "… close to 1:1, and the particles become more spherical.".

Lines 330-340: Re-calculate the radiative transfer using ensembles of particles, otherwise omit this part (see comment (3) above).