Response to Referee 1

We would like to thank the referee for her/his helpful comments and remarks. We expect the revised manuscript to address all comments.

We reproduce comments from the referee in "script" font followed by our answer. A document listing the revisions to the manuscript is also provided.

`General Comments:`

`This is a good, solid, and useful inter-comparison paper that can be accepted after minor revision. Since a vector radiative transfer model has been employed as a reference model, the polarization importance in radiative transfer applications could be further highlighted by a few additional citations. In addition to this, a deeper interpretation of the differences between the reference vector model and the scalar models should be given.`

We have added in the manuscript a reference to Barlakas (2016), indicating differences between scalar and vector approaches. We also have added, in the appendix, two figures comparing the model accuracy under high and low aerosol load (Figure A2 and A3), motivated by the comment by Referee 2. Figure A2 highlights differences between scalar and vector approaches. Additionally, the polarised reflectance over high and low aerosol load is now shown in Figure A4. The interpretation of Figure 4 has been expanded.

`Minor Comments:`

`1. Page 2, lines 20-22:`

`(A) "It should be noted that accounting . . .(e.g. Kotchenova et al., 2006)". This is true but it should be further elaborated to avoid generalizations. Some helpful comments that could be considered:`

`This holds true in case of pure molecular or pure aerosol atmospheres, where errors up to 11.5% and 5% are found, respectively (Mishchenko et al., 1994, Kotchenova et al., 2006, Barlakas 2016). In contrast to this, for realistic inhomogeneous atmospheres involving molecules, water soluble, and irregular shaped dust particles, the errors induced by neglecting polarization are insignificant, below 1% (Barlakas 2016). In the same direction are the findings of Hansen (1971). He reported that the corresponding vector versus scalar differences in case of spherical cloud particles (with sizes of the order or greater than the wavelength of the incident electromagnetic radiation) are below 1%.`

We thank the reviewer for his/her comment. Focusing on the clear-sky aerosol-laden atmosphere, we have added the following sentence:
"However, in cases where the atmosphere contains an important load of non-spherical particles (dust), errors in neglecting polarisation have been reported to be less than 1% (Barlakas, 2016)."

`(B) "but also because. . . polarised radiances (e.g. Tanré et al., 2011)." The polarization importance should be highlighted a bit more by adding more citations. For example, Illustrating the use of polarization in retrievals: Li et al. (2009) investigated the improvement in dust properties characterization resulting from additional polarization sun photometer measurements. In short, polarization helps constraining the size distribution, the real part of the refractive index, and determines a better non-spherical parameter.`

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Emde et al, 2018
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We have included the Dubovik et al. (2011) citation in the introduction.

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2. Page 15, lines 12-28: Some general comments and hints to help interpreting the deviations between scalar and vector calculations.
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(A) Concerning the dependency on the single scattering albedo for a given wavelength. It has been reported that the errors are decreasing with increasing single scattering albedo (Mishchenko et al., 1994, Barlakas, 2016).
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(B) line 17, "As expected,": An explanation should be given here. Here, are some hints: Aerosol scattering phase function is more polarized at longer wavelengths. In general, the aerosol contribution to the polarized reflectance is approximately proportional to its phase function and optical thickness (Bréon et al., 1997); For optical thickness larger than 1 - 2, the increasing multiple scattering process, leads to a decrease of the bias (scalar vs vector calculations), depending on isotropic reflection, and more importantly, on the single-scattering albedo (Mishchenko et al., 1994). Barlakas (2016) reported that these errors are subject to high-order multiple scattering and the asymmetric scattering phase matrices of irregular shaped particles (Strongly polarized first-order scattering supplies the second- order, and as a consequence, the second-order supplies the third-order, et cetera.); Outgoing TOA radiation becomes more polarized at longer wavelengths proportional to its phase function and optical thickness (Kotchenova et al., 2006).
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As the reviewer stated, Kotchenova et al. (2006) points out that the reflectances can be more polarised at longer wavelengths. But Kotchenova et al. (2006) refer only to two of their cases: pure aerosol (biomass burning) atmosphere, and a mixed aerosol and molecules atmosphere at 670 nm. They also stress the large difference between scalar and vector models at shorter wavelengths due to the more important contribution of molecular scattering over aerosol scattering. Summing this up, we have added this comment to the corresponding paragraph:

".As expected *and because of a larger molecular scattering contribution*, we observe larger... "

With respect of the differences between the scalar and vector RTMs, we have added to the manuscript Figures A2, and A4, along with the following explanations:

"... We also observe larger errors for the accumulation-mode aerosols (industrial scattering and industrial absorption have MFE $\approx 1.2\%$) in contrast to coarse-mode aerosols (dust and sea-salt have MFE $\approx 0.6\%$). *These errors are associated to the larger polarised phase function (see Figure 1) of industrial scattering and industrial absorption aerosols for large AOD (See Figures A2 and A4). Although no clear relation is shown for relative errors as function of the geometrical parameters in Figure 4, Figure A2 shows a clear link between the relative errors and the scattering angle for these two accumulation-mode aerosols at large AOD.* The oceanic BRDF function used in this study also enhances the errors of the scalar versions as these neglect the polarising effect of the surface*, because the glint can increase the polarised feature of the light for some angles*."

Regarding differences between 6SV2 and FLOTSAM against VLIDORT, we have added the following:

"... more pronounced forward scattering peak of the sea salt aerosols *their large single scattering albedo. In fact, errors for large AOD (Figure A3) are not strongly linked to the amount of polarised radiance (Figure A4) for sea salt aerosols. In the case of 6SV2, the coarse discretisation of the aerosol phase func-*

tion used in the model configuration (83 Gaussian points, Section 3.3) hampers the accurate simulation of the sea salt forward scattering peak."

Technical Corrections: Please see the attached file.

We have included the technical corrections in the manuscript.

Note that, in Emde et al. (2018) and https://www.meteo.physik.uni-muenchen.de/~iprt/doku.php?id=start, a list of vector radiative transfer applications and list of benchmark data are tabulated.

Hansen, J. E.: Multiple Scattering of Polarized Light in Planetary Atmospheres Part II. Sunlight Reflected by Terrestrial Water Clouds, Journal of the Atmospheric Sciences, 28, 1400- 1426, http://dx.doi.org/10.1175/1520-0469(1971)028<1400:MSOPLI>2.0.CO;2, 1971.

Mishchenko, M. I., Lacis, A. A., and Travis, L. D.: Errors induced by the neglect of polarization in radiance calculations for Rayleigh-scattering atmospheres, J. Quant. Spectrosc. Radiat. Transfer, 51, 491 - 510, http://dx.doi.org/10.1016/0022-4073(94)90149-X, 1994.

F.-M. Bréon, J.-L. Deuzé, D. Tanré, and M. Herman, "Validation of spaceborne estimates of aerosol loading from Sun photometer measurements with emphasis on polarization," J. Geophys. Res. 102(D14), 17187-17196 (1997).

Li, Z., Goloub, P., Dubovik, O., Blarel, L., Zhang, W., Podvin, T., Sinyuk, A., Sorokin, M., Chen, H., Holben, B., Tanr 0 e, D., Canini, M., and Buis, J.-P.: Improvements for ground- based remote sensing of atmospheric aerosol properties by additional polarimetric measurements, Journal of Quantitative Spectroscopy and Radiative Transfer, 110, 1954 - 1961, http://www.sciencedirect.com/science/article/pii/S002240730900154X, 2009.

Barlakas V: A new three-dimensional vector radiative transfer model and applications to saharan dust fields. University of Leipzig, Faculty of Physics and Earth Sciences; http://nbn-resolving.de/urn:nbn:de:bsz:15-qucosa-207467, 2016.

Emde C , Buras R , Sterzik M , Bagnulo S: Influence of aerosols, clouds, and sunglint on polarization spectra of Earthshine. Astron. Astrophys. 2017;605(A2) .

Pfreundschuh, S., Eriksson, P., Duncan, D., Rydberg, B., Håkansson, N., and Thoss, A.: A neural network approach to estimating a posteriori distributions of Bayesian retrieval problems, Atmos. Meas. Tech., 11, 4627-4643, https://doi.org/10.5194/amt-11-4627-2018, 2018.

We have added some of these references in the revised manuscript.

References

Barlakas, V. (2016). *A New Three–Dimensional Vector Radiative Transfer Model and Applications to Saharan Dust Fields.* PhD thesis, University of Leipzig. 108 p.

Dubovik, O., Herman, M., Holdak, A., Lapyonok, T., Tanré, D., Deuzé, J. L., Ducos, F., Sinyuk, A., and Lopatin, A. (2011). Statistically optimized inversion algorithm for enhanced retrieval of aerosol properties from spectral multi-angle polarimetric satellite observations. *Atmospheric Measurement Techniques*, 4(5):975–1018.

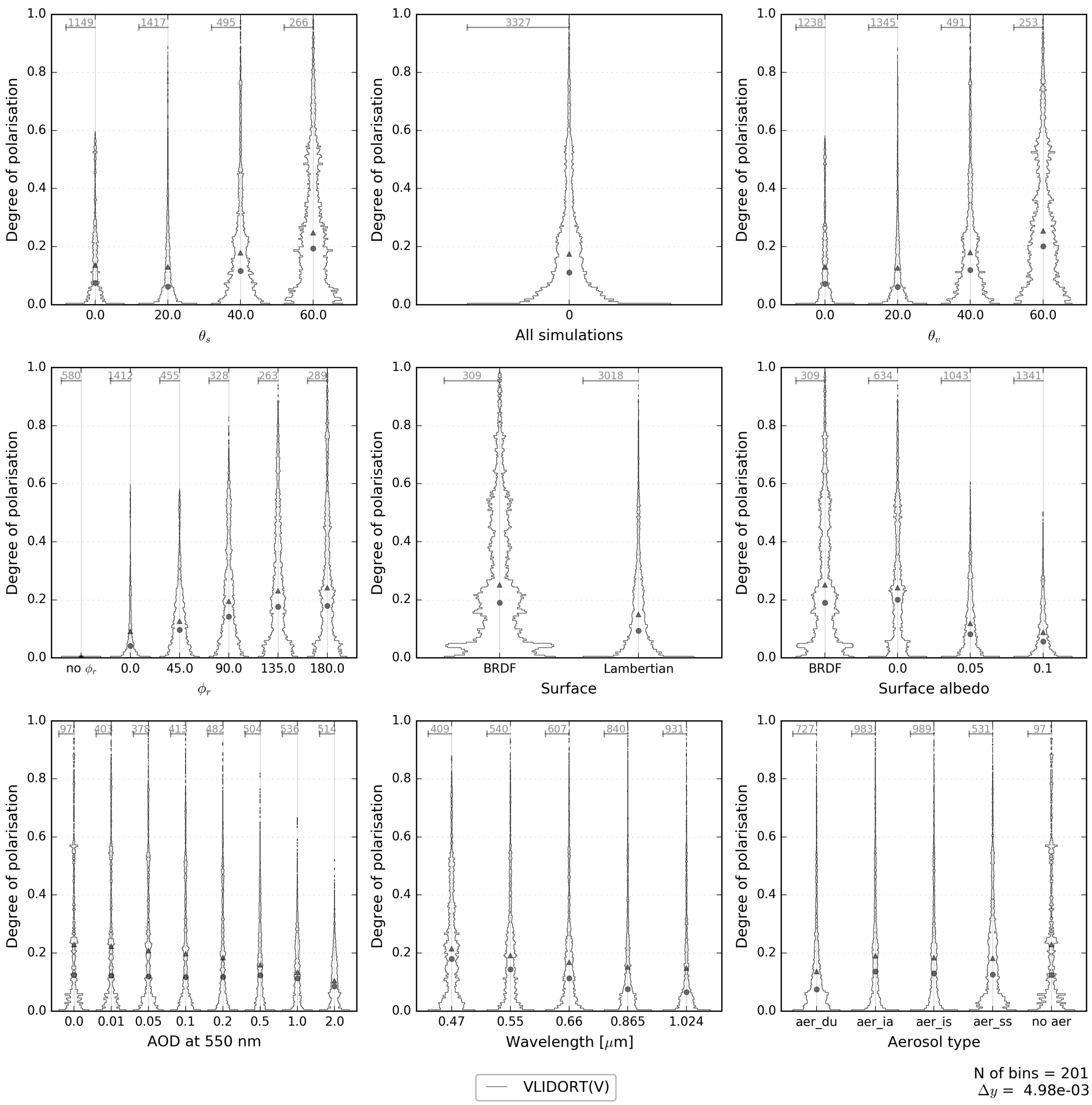

Figure 1: Violin plots showing the degree of polarisation computed with VLIDORT