**Response to Reviewer 1 by B. J. Elash et al.**

We would like to thank the referee for their helpful comments and suggestions. Below are the referee’s comments in italics followed by our reply

*Abstract: The abstract is good, but provides a summary that is not detailed enough. Please add specifically what was studied: aerosol signal fraction, retrieval bias and precision. Apart from the fact that linear polarization can be used as effectively as total radiance, also add the finding that horizontal polarization seems to be more promising in terms of signal magnitude.*

**Reply:** Response

*Sections 1:Third paragraph: A recent paper on the ALTIUS mission should be cited. Fussen, D., Dekemper, E., Errera, Q., Franssens, G., Mateshvili, N., Pieroux, D., and Vanhellemont, F.: The ALTIUS mission, Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-213, in review, 2016.*

**Reply:** Response

*Sections 1:Third paragraph: please explain briefly the technical reason why the use of an AOTF filter necessarily means that the obtained signals are linearly polarized.*

**Reply:** Response

*Section 2.1, third paragraph: please explain briefly (for general readability) how the Solar Scattering Angle (SSA) is defined.*

**Reply:** Response

*Section 2.1, third paragraph: “… angles of 0 and 180 degrees assuming horizontal atmospheric unity”. I don’t understand what is atmospheric unity. Do you mean homogeneity? Please clarify.*

**Reply:** Response

*Section 2.1, third paragraph: Fig. 1, caption: please indicated that these data were simulated with Sasktran, including multiple scattering.*

**Reply:** Response

*Section 2.2: please mention the reason for the pseudo-polarized approximation (likely processing speed).*

**Reply:** Response

*Section 2.3, Fig. 2: Please check the units of the aerosol extinction profiles. To me the values seem to be quite large. Shouldn’t this be km^-1 instead of cm^-1?*

**Reply:** Response

*Section 3: Sixth paragraph: The authors mention that no normalization is applied with respect to a shorter wavelength. I just want to comment that spectral normalization is one possible way to remove or minimize polarization effects since these vary less with wavelength than the spectral signature of atmospheric species.*

**Reply:** Response

*Section 3: Seventh paragraph: The authors mention that ozone, NO2 and albedo are fixed to the values used to simulate the measurements. This is of course legitimate in a study that focuses on aerosols, but it is necessary to take them into account in actual retrievals. Also, as I mentioned in the General Comments, the retrieval quality of these species depends on polarization as well. I would suggest to include an extra sentence here, to clarify that in actual operational retrieval schemes the need for fitting of the other species will induce extra retrieval uncertainty for aerosols.*

**Reply:** Response

*Section 3: “The assumption of a fixed particle size distribution …” etc. This sentence is too complicated. Please rephrase. Basically what the authors want to say is that they want to test the sensitivity of retrievals from polarized measurements to assumed particle size distributions. That should be enough.*

**Reply:** Response

*Section 4.1: Fig. 3: indicate in the caption what the different grey curves represent. It’s explained in the text, but a figure caption should clarify as much as possible by itself.*

**Reply:** Response

*Section 4.1: Last sentence of the section suggests that in the rest of the paper total radiance refers to the radiance I from the vector model, which is not true (if I understand well). Please change to “For the other cases presented, any …” or something similar.*

**Reply:** Response

*Section 4.2: Please state exactly (equations) what are the quantities that are being calculated (δ, δtot, δpol, Δδ). The discussion very rapidly becomes confusing if this is not known.*

**Reply:** Response

*Section 4.2: Spell out the abbreviation BRDF (bidirectional reflectance distribution).*

**Reply:** Response

*Section 4.2: Fig. 6: what is exactly shown? Is it the ratio of linearly polarized radiance to total radiance (as is written in the caption), or is it the ratio of linearly polarized aerosol signal to total radiance, as is written in the x-label of the figure? This is important, please clarify.*

**Reply:** Response

*Section 4.3: “The radiance calculations in the iterations of the retrieval were set to match …” etc. I really don’t understand this sentence. Please rephrase.*

**Reply:** Response

*Section 4.3: “There is no substantial difference between the results for the background and volcanic extinction profiles”. This is not correct, the sign of the bias is different (which, by the way,  isn’t surprising).*

**Reply:** Response

*Section 4.3: “This large bias is very sensitive to scattering angle and is nearly eliminated for even 85° or 95°”. Please make the sentence more clear by saying that farther away from 90° (below 85°, above 95°), the bias rapidly disappears.*

**Reply:** Response

*Section 5: Third paragraph: the authors describe the results for a compensated instrument, not for an uncompensated instrument. Please also include them.*

**Reply:** Response

*Abstract: … that are encountered in typical low earth orbit(s) …*

**Reply:** Response

*Abstract: (Taking into account instrument signal to noise capabilities, it) is found that in general, the linear polarization can be used as effectively as the total radiance measurement.*

**Reply:** Response

*Section 1: Stratospheric aerosols, which are (sub)micron-sized spherical …*

**Reply:** Response

*Section 1: … over the last decade was primarily caused by a series of (REMOVE somewhat) minor, mostly tropical …*

**Reply:** Response

*Section 1: The solar occultation technique has provided a robust and reliable method to retrieve aerosol (extinction) by directly measuring the atmospheric (transmittance). However, the (measurement frequency) of occultation measurements is somewhat limited … NOTE: ‘sampling rate’ is better reserved for the number of acquisitions per second during one occultation.*

**Reply:** Response

*Section 1: … and most recently (from) OMPS …*

**Reply:** Response

*Section 1: … using limb scattering including the (Belgian) instrument Atmospheric Limb Tracker …*

**Reply:** Response

*Section 2: … and the SASKTRAN-HR model … : please give abbreviation here, not further down in the text.*

**Reply:** Response

*Section 2: … where the (coefficients) of the Stokes vector, defined in …*

**Reply:** Response

*Section 2: The (4 x 4) scattering matrix is represented by …*

**Reply:** Response

*Section 2: … that is determined from the (Rayleigh-Gans) approximation …*

**Reply:** Response

*Section 2: The strong polarized nature can be (noticed) around (the) SSA of 90 degrees where the radiance is almost (completely) horizontally polarized.*

**Reply:** Response

*Section 2: … both Rayleigh and Mie scattering occur in a weighted fraction (determined by) the optical depth of air and aerosol.*

**Reply:** Response

*Section 2: … two panels of Figure 1 show the difference in the ratio of the polarized over the total radiance for the atmosphere with aerosol and (the) one without, (demonstrating that) this effect has a weak dependence on …*

**Reply:** Response

*Section 2: … but it obviously varies depending on (the) aerosol loading and …*

**Reply:** Response

*Section 2: The SASKTRAN framework … and number density profiles, and (assumes) a fully 3D …*

**Reply:** Response

*Section 2: At the end of section 2.2,the authors frequently use the word ‘scatter’ to indicate a scattering event (ex: the first two scatters in the atmosphere, the final scatter into the instrument). Is this correct? I’m not sure. Perhaps better use ‘scatter event’?*

**Reply:** Response

*Section 2: … of the scattering matrix (Rieger et al., 2014) [16]. (Aerosols scatter strongly) in the forward direction (resulting) in a weaker relative aerosol …*

**Reply:** Response

*Section 2: Caption of Fig. 2: The two aerosol (extinction) profiles used in this study. The blue (profile represents) background aerosol conditions, and …*

**Reply:** Response

*Section 2: To probe the range of possible viewing geometries from (a) low earth orbit, a range of …*

**Reply:** Response

*Section 2: … 1250 (and) 1500 nm, which approximately cover (REMOVE for) the spectral range …*

**Reply:** Response

*Section 3: The polarization states used here are defined as (follows): …*

**Reply:** Response

*Section 3: Due to (the non-linear behaviour of) multiple scattering, … at most stratospheric tangent altitudes (the atmosphere is optically quite thin at the considered wavelengths) and this simple percent difference …*

**Reply:** Response

*Section 3: … that is essentially similar to (the one) developed by Bourassa et al. …*

**Reply:** Response

*Section 3: … is then used to retrieve aerosol extinction profiles using the (technique of) Bourassa et al. …*

**Reply:** Response

*Section 3: … which describes the sensitivity of the retrieval to the measurement and the respective noise through the following (equation) (Rodgers, 2000) [31]:*

**Reply:** Response

*Section 4: Fig. 4, x-label. Better use “Rel. difference” than “Error”. It’s not an error, it’s a difference between two different retrievals.*

**Reply:** Response

*Section 4: Fig. 4, caption: Each (panel) represents a different particle size …*

**Reply:** Response

*Section 4: These were used as input measurements (for the retrieval), which was then performed …*

**Reply:** Response

*Section 4: A case-by-case comparison … was performed (by calculating) siple percentage differences(s) at each (retrieval) altitude. (These have been shown as) grey lines in Fig. 3.*

**Reply:** Response

*Section 4: These results (REMOVE given in Fig. 3) show that across all …*

**Reply:** Response

*Section 4: The viewing geometry, which is (typical for a) low earth orbit scenario, is (given by) SZA =  45° and …*

**Reply:** Response

*Section 4: Fig. 4, caption: … particle size distribution 1. (Notice that) the red-blue scale is (asymmetric).*

**Reply:** Response

*Section 4: Fig. 5, caption: Dependence of the fraction of the limb spectra (at 15 km) due to aerosol on …*

**Reply:** Response

*Section 4: … were performed for the full range of SZAs. We found that …*

**Reply:** Response

*Section 4: … was found that these two polarization orientations had (a) similar aerosol …*

**Reply:** Response

*Section 4: … with very low signal magnitude near (the scattering angle of 90°).*

**Reply:** Response

*Section 4: … will cover forward and backward scattering angles, including (the 90° scattering angle), it is ….*

**Reply:** Response

*Section 4: … is shown for a series of SSA (and) a tangent altitude of 20 km, …*

**Reply:** Response

*Section 4: … total radiance, with the greatest (signal reduction) at the shorter …*

**Reply:** Response

*Section 4: Back scatter geometries are (marginally) better with …*

**Reply:** Response

*Section 4: In all cases, the retrieval was performed (assuming a fixed log-normal particle size distribution with a) mode radius and width of ….*

**Reply:** Response

*Section 4: … the major element of observed bias is simply (due to the) difference between the true …*

**Reply:** Response

*Section 4: … various viewing geometries. (None) of the linearly polarized states perform any worse either …*

**Reply:** Response

*Section 4: … were calculated for each retrieved state and used (to) determine the gain matrices, …*

**Reply:** Response

*Section 4: … due to small sensitivity (at) the lower tangent altitudes … from the data set (approximately 9% of (all) cases). …*

**Reply:** Response

*Section 4: For the (compensated) case, (REMOVE where the signal to noise ratio is … for all cases) the measurement …*

**Reply:** Response

*Section 4: The fainted colours (represent) one standard deviation (around) the mean. Each of the means in … data points(. Values smaller or larger than one respectively indicate retrieval uncertainties smaller or larger than the total radiance retrieval uncertainties).*

**Reply:** Response

*Section 4: … Recall, however, that the vertical polarization has significantly lower (REMOVE magnitude) signal levels and …*

**Reply:** Response

*Section 4: … SSA for the horizontal and vertical polarizations(. Note that) the SSA of 90° is missing due to the poor signal, (and the associated high retrieval co-variances for this geometry).*

**Reply:** Response

*Section 4: … compared to the total radiance case the decreased precision is (larger for the horizontal polarization) at shorter wavelengths.*

**Reply:** Response

*Section 5: … of linearly polarized radiance rather than total limb radiance (represents) an advantage or …*

**Reply:** Response

*Section 5: The sensitivity of the polarized … is (a complicated function of) many parameters, …*

**Reply:** Response

*Section 5: One critical bias … is (caused by the) uncertainty in (the assumed) particle size parameters.*

**Reply:** Response

*Section 5: … the magnitude of the signal. (For a compensated instrument, the) polarization can either …*

**Reply:** Response

*Section 5: … aerosol products of very similar quality (compared) to an equivalent instrument …*

**Reply:** Response

**Response to Reviewer 2 by B. J. Elash et al.**

We would like to thank the referee for their helpful comments and suggestions. Below are the referee’s comments in italics followed by our reply

*Abstract:  Add more information on the findings of this work.  All you have is one somewhat vague sentence (“...linear polarization can be used as effectively as the total radiance …”).  Half the abstract is preamble/context as well, which is unnecessary.*

**Reply:** Response

*Intro, line 4:  aerosol composition is also very important*

**Reply:** Response

*Page 2, line 5:  “directly measuring the atmospheric optical depth” – the measurement is of slant path extinction.*

**Reply:** Response

*Page 2, line 6:  remove “somewhat”*

**Reply:** Response

*Page 4, para 3, “easy seen”à Add the equation for polarization (or linear polarization)*

*Section 2.2:  provide a sentence or two on how appropriate it is to assume the surface is completely depolarizing.*

**Reply:** Response

*Figure 2:  provide the vertical AODs for these extinction profiles*

**Reply:** Response

*General question: Can you comment on how your results might be affected if a different inversion approach is used?  I would guess that at the bottom of the retrieval range, different methods would have different sensitivities.*

**Reply:** Response

*Figure 7:  Could it be suggested that based on Figure 7, the vertical component performs better for situations where a single mode might be more representative such as non-volcanic periods?*

**Reply:** Response