Reply to Referee #1:

We thank the referee for the constructive and positive review.

1. *Line 58: Make it clear the e is not only the measurement error, but also contain the modeling error.*

   Response:

   We agree. We have revised it in '2.1 Forward model':

   'where $\boldsymbol{e_y}$ refers to the error vector including measurement error and modelling error.'

2. *Line 63: I understand that the RemoTAP algorithm uses the degree of polarization to quantify his piece of information. In my opinion, it would have been better to use the Stokes parameter Q (normalized similarly to I) with the plane of scattering as a reference. Indeed, Q then contains both the intensity of the polarized reflectance and some information about the direction (perpendicular versus parallel to the scattering plane).*

   Response:

   We believe both approaches have advantages and disadvantages. The advantage of using *DoLP* is that it is a relative quantity where multiplicative (calibration) errors in *I*, *Q*, and *U* cancel out. The disadvantage is to have 2 quantities in the measurement vector (*I*, *DoLP*) that are not independent. Using *Q* in the scattering plane (or polarized radiance) is more sensitive to calibration errors but has the advantage of having independent quantities in the measurement vector. In the past we have performed some sensitivity studies for PARASOL where using *DoLP* had a slight advantage for aerosol retrievals.

3. *Table 1: I am a bit surprised to see so many aerosol parameters that are retrieved. In particular, I doubt that there is sufficient information in the data to estimate the aerosol height for three different modes. Is there any value in the retrieved aerosol height properties? Also, there is no height for mode 3, opposite to mode 1 and 2. Any reason for that?*

   Response:

   We agree that PARASOL data provide weak feasibility to retrieve ALH because the shortest wavelength polarization band (490 nm) is quite far from the UV. However, there is still some sensitivity, and we see the retrieval of other aerosol properties improves of we include ALH in the state vector. Mode 3 represents sea salt which we assume is in the boundary layer and we do not retrieve ALH. Mode 1 (fine mode) and mode 2 (representative for Dust) can consist of elevated layers. Although indeed we do not have independent information on ALH for mode 1 and 2 separately, it still has advantage to include them separately in the state vector, for cases where one of the 2 modes dominates the aerosol distribution.

4. *I understand that the modeling assumes that the surface reflectance BRDF shape does not vary with wavelength. This a strong assumption. Indeed, the surface reflectance amplitude varies strongly with wavelength and high albedos tend to generate more isotropic reflectance than low albedos. Would it be possible to add some freedom in the spectral variation of the BRDF modeling?*

   Response:

In our algorithm, the wavelength-dependence for the isotropic reflectance $A(\lambda)$ has been already considered. The isotropic reflectance $A(\lambda)$ is fitted for different bands, and it is shown in equation (5) in '2.1 Forward model'. However, the kernel coefficients (k_{geo}, k_{vol}, k_{snow} in Eq. 5) do not depend on wavelength in RemoTAP and it would be a major code change to modify that. Based on Litvinov et al. (2011) this assumption is justified for vegetation and soil surfaces. Given that we can fit the PARASOL measurements well between 444-865 nm this assumption also does not seem to be a limitation for snow surfaces in the VNIR. The problem with the 1020 nm band in our retrievals is not caused by the assumption of a constant k_{snow} because we can reproduce it with consistent synthetic measurements.

5. *Line 165: In the real world, the measurement of DoLP is more noisy in case of low reflectances than with high reflectances. It is then unfortunate to use a fixed DoLP uncertainty that does not depend on the scene*

   We agree this is a limitation of this setup which and we will investigate improvements in the near future. On the other hand, in the inversion approach of RemoTAP it is the balance between noise in radiance and DoLP that is of importance and not so much the assumed value itself.

6. *Table 3: What are the rationale for setting these min and max? Why some values are missing?*

   Response:

   The min and max values are based on an inspection of global PARASOL retrievals, where appropriate. We revised the table and the following paragraph to give more details and avoid misunderstanding:

   '

Table 3: Observation geometry, aerosol properties and surface properties used to create synthetic PARASOL observations. c_{veg}, c_{soil} and c_{snow} are the fraction of vegetation, soil and snow respectively. Distribution 'linear' refers to $X \sim \mathrm{U}(X_{min}, X_{max})$, and distribution 'logarithmic' refers to $\ln X \sim \mathrm{U}(\ln X_{min}, \ln X_{max})$, where X is the property value, X_{min} and X_{max} are the minimum and maximum respectively.

Property	Minimum	Maximum	Distribution
θ_s	10	70	logarithmic
θ_v	-65	65	$0, \pm10, \pm20, \pm30, \pm40, \pm50, \pm60, \pm65$
φ	20	160	$\varphi = 20$ when $\theta_v \geq 0$, $\varphi = 160$ when $\theta_v < 0$
c_{veg}	0.0	1.0	linear or fixed (see Table 4)
c_{soil}	0.0	1.0	linear or fixed (see Table 4)
c_{snow}	0.0	1.0	linear or fixed (see Table 4)
τ_{550} (mode 1)	0.005	1.0	logarithmic
τ_{550} (mode 2)	0.0025	0.25	logarithmic
τ_{550} (mode 3)	0.0025	0.25	logarithmic
r_{eff} (mode 1)	0.1	0.3	linear
r_{eff} (mode 2)	0.8	1.5	linear
r_{eff} (mode 3)	1.5	4.0	linear
v_{eff} (mode 1)	0.1	0.3	linear
v_{eff} (mode 2)	0.6	0.6	fixed
v_{eff} (mode 3)	0.6	0.6	fixed
f_{sph} (mode 1)	1.0	1.0	fixed

f_{sph} (mode 2)	0.0	0.0	fixed
f_{sph} (mode 3)	1.0	1.0	fixed
z_{aer} (mode 1)	1000	6000	linear
z_{aer} (mode 2)	1000	6000	linear
z_{aer} (mode 3)	500	500	fixed

The surface properties in the synthetic data set are created by mixing the contribution of the surface reflection by vegetation, soil, and snow. By controlling the fraction of vegetation, soil and snow, 4 sets of synthetic measurements are created, where the detailed information for these 4 synthetic measurements are listed in Table 4. The isotropic reflectance $A(\lambda)$ is calculated with equation $A(\lambda) = c_{\mathrm{veg}}A_{\mathrm{veg}}(\lambda) + c_{\mathrm{soil}}A_{\mathrm{soil}}(\lambda) + c_{\mathrm{snow}}A_{\mathrm{snow}}(\lambda)$. $A_{\mathrm{veg}}(\lambda)$. $A_{\mathrm{soil}}(\lambda)$ and $A_{\mathrm{snow}}(\lambda)$ refer to the reference reflectance spectra for vegetation, soil and snow (shown in Figure 1). For the kernel coefficients of Li-Sparse ($k_{\mathrm{geo}} = 0.087c_{\mathrm{veg}} + 0.158c_{\mathrm{soil}}$) and Ross-Thick ($k_{\mathrm{vol}} = 0.688c_{\mathrm{veg}} + 0.547c_{\mathrm{soil}}$), the constant values we use are found by Litvinov et al. (2011).'

7. *Figure 3 and 4: Explain color coding*

   Response:

   The explanation of color coding is added:

   'The color indicates the density of data points, where yellow indicates high density and blue/purple low density (viridis color map).'

Reference:

Litvinov, P., Hasekamp, O., and Cairns, B.: Models for surface reflection of radiance and polarized radiance: Comparison with airborne multi-angle photopolarimetric measurements and implications for modeling top-of-atmosphere measurements, Remote Sensing of Environment, 115, 781-792, https://doi.org/10.1016/j.rse.2010.11.005, 2011.