Reply to Referee #2:

We thank the referee for the constructive and positive review.

1. *Line 83: Snow kernel function is given below the equations (6-7). I would say it is better to refer it and show its equation only on 87th line as it is.*

   Response:

   We agree that the equation (8) is the primary function for snow kernel but also Eq. 9 and 10 are important to include for the reader to know exactly how we used the kernel of Jiao et al. (2019). We removed the phrase 'in Eq. (8)' just before Eq (8) because it may suggest that it refers to Eq (8) of Jiao et al. (2019).

2. *Line 68: It's unclear to me if with the term z_aer you mean the top or the bottom of the aerosol layer. Other retrievals separate these two terms so here it's a bit confusing.*

   Response:

   The term aerosol layer height (ALH) z_aer refers to the altitude of the centre of aerosol layer, that is z_aer = 0.5*(z_bottom+z_top). We add a definition at the place where ALH first appears in our manuscript:

   'aerosol layer height (z_{aer}, here refers to the altitude of the aerosol layer centre)'

3. *Table 1: For the 3rd Mode add the fixed z_aer as it is noted on line 74, so the reader doesn't have to search for this information in the text.*

   Response:

   Thanks for your suggestion. We have added it.

4. *AERONET utilized for collocation purposes is introduced in the previous paragraph, but I think it would be better if you add AND here something like "in terms of AOT, SSA, AE" because I had to look up to the AERONET data to remember this.*

   Response:

   Thanks for your suggestion. In this way, the readers do not have to look back and check for the information. We have revised it in '3.5 Data pre-processing':

   'The first step is to match global PARASOL L1 measurement data with global AERONET validation data (AOT, SSA & AE).'

5. *Table 3: The minimum and maximum values give the range of the randomly generated input parameters? Is there a reason you choose these limits?*

   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 $X \sim \mathrm{U}(X_{\mathrm{min}}, X_{\mathrm{max}})$, and distribution 'logarithmic' refers to $\ln X \sim \mathrm{U}(\ln X_{\mathrm{min}}, \ln X_{\mathrm{max}})$, 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 $A(\lambda) = c_{veg}A_{veg}(\lambda) + c_{soil}A_{soil}(\lambda) + c_{snow}A_{snow}(\lambda)$. $A_{veg}(\lambda)$. $A_{soil}(\lambda)$ and $A_{snow}(\lambda)$ refer to the reference reflectance spectra for vegetation, soil and snow (shown in Figure 1). For the kernel coefficients of Li-Sparse ($k_{geo} = 0.087c_{veg} + 0.158c_{soil}$) and Ross-Thick ($k_{vol} = 0.688c_{veg} + 0.547c_{soil}$), the constant values we use are found by Litvinov et al. (2011).'

6. *Figure 2: The general better performance of extended RemoTAP is clear. If you changed the χ2 limit for the filtering do you think it would have better results for SSA (maybe a sensitivity test)? The difference of 0.008 (RMSE) between baseline and extended RemoTAP over snow_domi surfaces appears small but in terms of % relative difference it is not insignificant. I'm thinking if it would be more proper using the baseline RemoTAP for SSA.*

   Response:

   Here are two reasons why we recommend 4-band extended RemoTAP for aerosol retrieval over snow: (1) RemoTAP is a full-physical algorithm, so AOT and SSA are not retrieved separately. We first retrieve microphysical properties of aerosol and then calculate and output AOT and SSA. Therefore, using two versions of RemoTAP to retrieve AOT and SSA harms the microphysical relationship between AOT and SSA and would further lead to the contradictions related with physical basis; (2) RemoTAP algorithm will be used to generate the global aerosol products of

NASA SPEXone/PACE, so we have to consider the processing speed. Since the global data processing is time-consuming, if we output SSA and AOT product with two versions of RemoTAP, it would double the processing time, therefore we would prefer to choose one comprehensively good-performance version of RemoTAP to generate both SSA and AOT products in the same run.

7. *Figure 3: Why x-axis is labeled as Truth and not AERONET and y-axis as Retrieval and not Extended RemoTAP? I had to read the caption to understand the figure.*

Response:

Figure 3 belongs to the section '4 Synthetic data experiments', so the x-axis does not refer to AERONET data but refer to the truth which is used to simulate the synthetic measurements. In addition, Figure 4 belongs to the section '5 Real data experiments' and the x-axis refers to AERONET data. In order to better distinguish these two figures and avoid misleading, we revised Figure 3 with new axis labels and figure caption:

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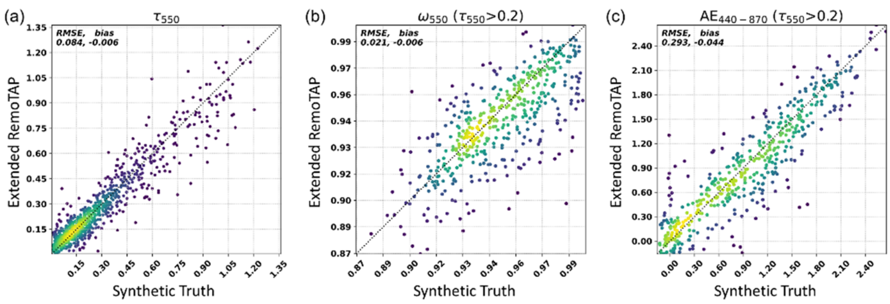

Figure 3: Synthetic data retrievals of τ_{550}, ω_{550} and $AE_{440-870}$ among extended RemoTAP retrievals versus synthetic truth over pure snow surfaces ($c_{snow} = 100\%$). Panels (a, b, c) show the scatter-plot of τ_{550}, ω_{550} and $AE_{440-870}$, respectively.

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Reference:

Jiao, Z., Ding, A., Kokhanovsky, A., Schaaf, C., Bréon, F.-M., Dong, Y., Wang, Z., Liu, Y., Zhang, X., Yin, S., Cui, L., Mei, L., and Chang, Y.: Development of a snow kernel to better model the anisotropic reflectance of pure snow in a kernel-driven BRDF model framework, Remote Sensing of Environment, 221, 198-209, https://doi.org/10.1016/j.rse.2018.11.001, 2019.

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.