Report 2

Reply to Anonymous Referee #1

This article develops a numerical method for simultaneously retrieving AOD, SSA and DHR from DPC multi-angle polarimetry (MAP) observations. The authors analyze the sensitivities of both scalar and polarimetric reflectance to SSA, and get reliable results of global AOD, SSA, and DHR based on the retrieval algorithm. As one of the few operational spaceborne MAP sensors, inversion algorithms based on DPC observations, particularly those for SSA retrieval, remain quite limited, with few global SSA products currently available. This study provides a reference for the design of future MAP sensors and the development of aerosol retrieval algorithms. The global SSA maps presented in this article also provide valuable insights into aerosol scattering and absorption characteristics in recent years. However, several aspects of the data, methods, and results require further clarification and improvement.

We thank the reviewer for the detailed comments and thoughtful suggestions, which are very helpful in improving our manuscript. We have carefully addressed all concerns and revised the manuscript accordingly. A point-by-point response is presented below.

General comments:

1. Data used in the article: The authors retrieve aerosol and surface parameters from DPC measurements, and validate the retrieved results according to comparing with AERONET and MODIS products. However, there are several points need to be clarified. (1) DPC data: The description of DPC data is not very clear. The authors introduce that DPC provide observations across 8 spectral bands, but only 5 bands are mentioned in Section 2.1. Moreover, the use of polarized observations is also not specified. (2) AERONET data: The authors use all the Level 2.0 quality control criteria except AOD threshold to screen the AERONET Level 1.5 SSA. But the 0.4 AOD threshold are still utilized to screen the SSA in the validation progress. Why

not directly utilize the Level 2.0 SSA data? (3) The periods of DPC and AERONET data used in the article are not specified.

We thank the reviewer for the suggestion about the usage of data in the article.

(1) DPC data: We have revised the manuscript and listed all the DPC channels in L73:

The sensor provides measurements across 8 spectral bands (443, 490, 565, 670, 763, 765, 865, and 910 nm) from visible to near-infrared wavelengths.

The use of DPC observations have been listed in Table 2 and clarified in L167:

The measurement vector, $\boldsymbol{y}$, is constructed with calibrated scalar reflectance at 443, 490, 565, and 670, as well as DOLP at 490 and 670 nm from several angles.

(2) AERONET data.

Although AERONET Level 2.0 SSA data provide the highest quality, the number of available Level 2.0 SSA retrievals during the study period (6 months) is very limited, which would not allow a statistically meaningful validation of the algorithm performance. In order to balance the data quality and data availability, all Level 2.0 quality control criteria except for the AOD threshold were applied to the Level 1.5 data. Moreover, the AOD threshold ($\mathrm{AOD}_{440} > 0.4$) was applied only in the SSA validation step and was based on the retrieved AOD, rather than the AERONET AOD. This filtering was introduced to exclude cases with insufficient sensitivity of the measurements to SSA, and it was not applied to the validation of AOD or DHR. Therefore, quality-controlled AERONET Level 1.5 data were used in this study.

(3) Periods of data:

We thank the reviewer for pointing out this missing information. In the revised manuscript, we have explicitly specified the time periods of both the DPC and AERONET data used in this study. Six months of DPC Level 1 data, covering April, July, and October 2019, as well as January–March 2020, are used for the retrieval. The AERONET observations used for validation correspond to the same periods as the DPC overpasses. This information has been added in L75:

Six months of DPC Level 1 data, encompassing April, July, and October 2019, as well as January-March 2020, are used in the retrieval in this study. The AERONET, MODIS, as well as other auxiliary data are selected from the same periods.

2. Retrieval algorithm: The authors have provided a detailed description of the retrieval algorithm, but the introduction to the flowchart could be strengthened by providing more details. The authors can consider the following aspects. (1) The DPC observations have "up to 12 viewing angles" and typically "exceeding 9 angles". Are observations from all the angles used for inversion? What about those pixels with viewing angles less than 9? (2) Which method is employed to minimize the cost function? (3) What criteria are utilized for the matching of DPC and AERONET data?

We thank the reviewer for the suggestion about the retrieval algorithm in the article.

(1) In this study, only pixels with at least 9 valid viewing angles were used for the inversion. Pixels with fewer than 9 viewing angles, which are primarily located near the scan edges, were excluded to ensure sufficient angular sampling. For the remaining pixels, observations from the first 9 viewing angles were used for the retrieval to maintain a consistent angular configuration across all pixels. We have added the relevant description in the manuscript in L170:

However, most pixels are observed from more than 9 viewing angles. Pixels with fewer than 9 viewing angles, which are primarily located near the scan edges, were therefore excluded. For the remaining pixels, observations from the first 9 viewing angles were used in the retrieval to maintain a fixed number of viewing angles for all pixels. Consequently, the scalar reflectance and DOLP at each wavelength consist of measurements acquired from 9 viewing angles.

(2) In this study, the cost function is minimized using an iterative Gauss–Newton method. This information has been added to the revised manuscript in L201:

The algorithm minimizes the cost function defined in Eq. 4 using an iterative Gauss–Newton method to obtain the final retrieval results.

(3) In the numerical simulation experiments, daily AERONET data are used to describe representative aerosol parameters, and a spatial collocation radius of 8 km is used. We have added the relevant description in the manuscript in L223:

The simulated dataset was constructed using aerosol parameters derived from daily AERONET observations selected within an 8 km radius of DPC overpass locations to represent typical aerosol conditions observed by DPC. The corresponding viewing geometry, including SZA, VZA, and RAA, was taken from the matched DPC observations and used in the radiative simulations, thereby accounting for the actual scattering angle distribution of DPC observations.

3. Validation results: The authors analyzed several statistical indicators (e.g., correlation coefficient, RMSE, bias) to validate retrieval results. For SSA validation, the ratio of points falling within the Error Envelope (EE) is also a useful indicator to assess the result. It would be helpful to add EE lines to the figures and annotate the corresponding point ratios.

Thanks for the very helpful suggestion. We have added the ± 0.03 Error Envelope (EE) lines to the SSA validation scatter plot and indicated the proportion of samples falling within the EE in the figure. Corresponding analysis has also been added in the manuscript.

4. Global maps: Section5 shows global retrieval results. These maps provide valuable insights into aerosol and surface properties. I have two comments about these results. (1) The authors explain that the zonal discontinuities in the maps are primarily due to defects in the original data. However, the discontinuities observed over oceanic areas also seems to be related to the incompletely filtered clouds. Would be better to clarify in the manuscript. (2) Heavy AOD is observed over Southern Oceans in January 2020. The authors attributes it to the strong Australian wild fires. However, the AOD over Southern Oceans almost reaches 0.5 in Fig. 10(d). Is this magnitude reasonable? Was it also observed by other sensors?

We thank the reviewer for the helpful comments.

(1) We agree that the zonal discontinuities observed over oceanic regions may also be related to incompletely filtered clouds, in addition to defects in the original data. In

this study, cloud screening also relies on observations at 865 nm, which have not been re-calibrated and can have higher uncertainties (up to about 23%). As a result, cloud pixels may not be completely removed. We have revised the manuscript to clarify this limitation and added a discussion acknowledging that residual cloud effects related to the cloud screening procedure may contribute to the observed discontinuities.

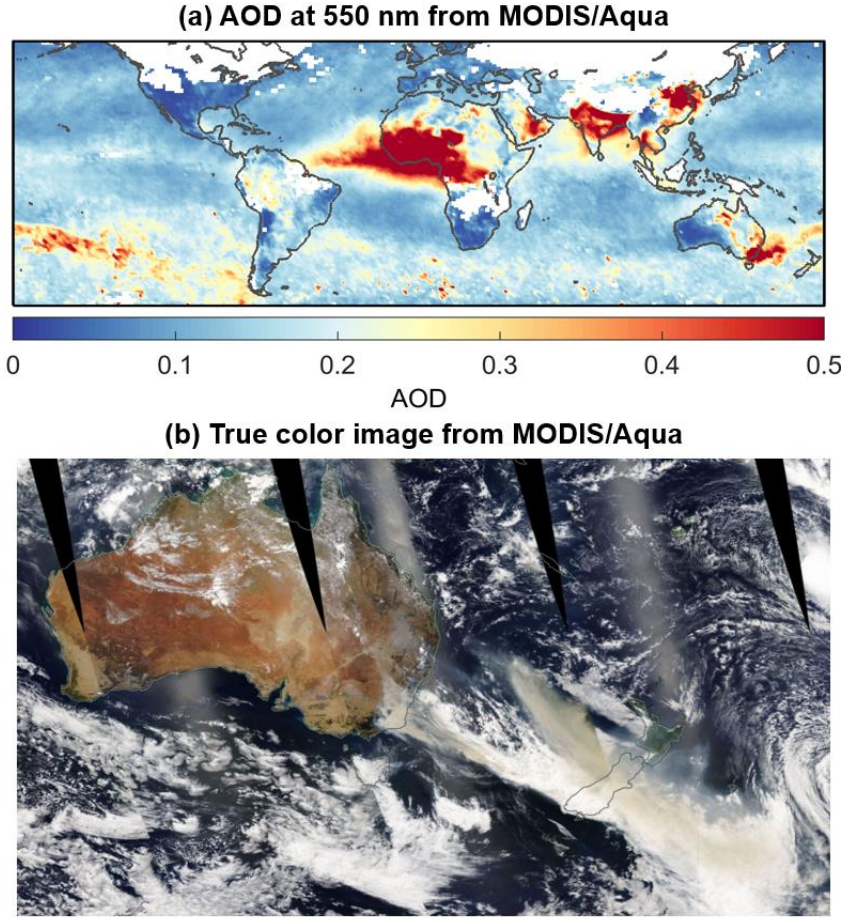

Fig. R2-1. (a) Global AOD for January 2020 at 550 nm from MODIS/Aqua Level 3 product. (b) True color image from MODIS/Aqua on January 1, 2020.

(2) As for the abnormally high AOD values observed over the Southern Ocean, we conducted further examinations using true-color imagery and MODIS AOD products. The true-color imagery (Fig. R2-1b) for early January 2020 reveals extensive smoke plumes over the Southern Ocean originating from southeastern Australia and gradually transported eastward. This indicates that large amounts of

biomass-burning aerosols were present over the region during this period. The MODIS monthly AOD product for January 2020 also shows anomalously high AOD over the Southern Ocean, with values exceeding 0.5 in some areas (Fig. R2-1a). The spatial pattern and magnitude are generally consistent with our retrieval results. Thus this magnitude is likely reasonable. We have added the corresponding MODIS AOD map to the Supplement material, and included a relevant discussion in the manuscript in L440:

The anomalously high AOD over the Southern Ocean in January 2020 reaches values of up to 0.5 in some regions, consistent with independent data sources (e.g., MODIS AOD, see Supplement).

Minor comments:

1. L68: The calculation of DOLP is not described in the article.

Thanks for reminding. We have added an equation (Eq. 7) of calculating DOLP in the manuscript in Sect. 2.6.

2. Fig. 2-4: Please explain the x label "scat_ang" in the caption.

Thanks for reminding. The xlabel "scat_ang" refers to "scattering angle", and we have explained in the caption of Fig. 2.

3. Fig. 7: DHR data are not AERONET observations. Please revise the caption.

Thanks for reminding. We have revised the caption of Fig. 7 to clarify the data sources:

Comparison between retrieved AOD (left) and SSA (middle) at 443 nm and AERONET observations, and comparison between retrieved DHR (right) at 443 nm and the MODIS product.

4. Section 3.2: Please keep the number of significant digits consistent.

Thanks for pointing it out. We have carefully checked Section 3.2 and revised the manuscript to ensure that the number of significant digits is used consistently throughout this section.

5. Fig. 8: The “(a)/(b)/(c)” labels are not marked in the figures.

Thanks for reminding. We have added labels in Figs. 8 and 9.

6. Figs. 8-12: The wavelength labeled in the figures (440 nm) does not match the wavelength mentioned in the text (443 nm). Please update either the figures or the relevant text for consistency.

Thanks for pointing out this inconsistency. The wavelength labels have been carefully checked and updated for consistency. All references have now been unified to 443 nm in both the figures and the corresponding text.