Respond to Reviewer #1

Dear reviewer, thanks for your comments. We have carefully read your comments, and replied to your comments point by point with corresponding modifications in the manuscript. In the following, your comments are marked in bold italics, our responses are in black, and the modifications in manuscript are shown in blue.

This study estimates the aerosol detect performance of DPC and verifies the accuracy of AOD retrieval with the GRASP Algorithm. It provides a complete set of DPC data pre-processing flow, and introduces the necessary information of the DPC and GRASP algorithms. In addition to the AERONET, the results of AOD were also compared with various MODIS standard aerosol products at spatial and temporal scales. Generally, the manuscript has been well organized and written. It is worthy for publication after some minor modifications. The comments were as follow.
Major Comments:

Thanks for your comments and recognitions. We have carefully checked your comments and revised the manuscript. The detailed replies are as follows.

1) The DPC/Gaofen-5 is the first multiple angles and polarization satellite sensor developed by China. Thus, it is recommended to add a brief introduction to the DPC sensor in the Abstract section to help readers quickly understand the sensor.

Thank you for these suggestions. We added some appropriate additions in the Abstract to introduce the DPC sensors. We believe it is useful for readers. The specific modifications are as follows:

Line 20-25: Directional Polarimetric Camera (DPC) is the first generation of multi-angle polarized sensor developed by China. It is onboard GaoFen-5 satellite, running in 705 km sun-synchronous orbit with a 13:30 pm ascending node. The sensor has three polarized channels at 490, 670, and 865 nm and ~9 viewing angles, mainly used for observing aerosols. The spatial resolution is ~ 3.3 km at nadir and global coverage is in ~2 days.

2) For the Method section, I noticed an additional radiometric correction applied to the DPC data prior to AOD inversion. Is this necessary and does it have a big impact on the results?

Thanks for your comments. Yes, this step is important to control data quality of DPC. From the report of pervious study [1], the DPC reflectance has a negative bias and it can reach -20% after launch. Therefore, the retrieval of aerosols is difficult to perform without attempting to correct for these large deviations.

[1] Zhu, S., Li, Z., Qie, L., Xu, H., Ge, B., Xie, Y., Qiao, R., Xie, Y., Hong, J., Meng, B., Tu, B., & Chen, F. (2022). In-Flight Relative Radiometric Calibration of a Wide Field of View Directional Polarimetric Camera Based on the Rayleigh Scattering over Ocean. Remote Sensing, 14 (DOI: 10.3390/rs14051211)

3) As mentioned in Section 3.3, the setting of multi-pixel retrieval unit in the GRASP can help to improve result of AOD inversion. What is the basis for this setting? Does a larger inversion unit mean better inversion results?

Thanks for your comments. The size of multi-pixel retrieval units can be customized according to the experimental needs. In most cases, the setting of it depends on computer hardware conditions: the larger the retrieval unit, the larger the memory required, and the slower the calculation speed. This multi-pixel concept introduced by Dubovik et al. (2011) allows for benefiting from a priori knowledge on spatial and temporal variability of retrieved parameters and therefor helps to obtain more accurate aerosol retrieval. For example, it is well known that land surface reflectance changes very slowly in time, while aerosol properties have limited spatial variability. Some more discussion can be found in Dubovik et al. (2011, 2021) . As shown in Figure 3 in the manuscript, the increase of ambient pixels and timesteps reduces the inversion bias.

[1] Dubovik, O., Herman, M., Holdak, A., Lapyonok, T., Tanré, D., Deuzé, J.L., Ducos, F., Sinyuk, A., & Lopatin, A. (2011). Statistically optimized inversion algorithm for enhanced retrieval of aerosol properties from spectral multi-angle polarimetric satellite observations. Atmospheric Measurement Techniques, 4, 975-1018, doi:10.5194/amt-4-975-2011

[2] Dubovik, O., Fuertes, D., Litvinov, P., Lopatin, A., Lapyonok, T., Doubovik, I., Xu, F., Ducos, F., Chen, C., Torres, B., Derimian, Y., Li, L., Herreras-Giralda, M., Herrera, M., Karol, Y., Matar, C., Schuster, G.L., Espinosa, R., Puthukkudy, A., Li, Z., Fischer, J., Preusker, R., Cuesta, J., Kreuter, A., Cede, A., Aspetsberger, M., Marth, D., Bindreiter, L., Hangler, A., Lanzinger, V., Holter, C., & Federspiel, C. (2021). A Comprehensive Description of Multi-Term LSM for Applying Multiple a Priori Constraints in Problems of Atmospheric Remote Sensing: GRASP Algorithm, Concept, and Applications. Frontiers in Remote Sensing, 2:706851, doi:10.3389/frsen.2021.706851

4) In the result of AOD, the large absolute mean bias also appeared when the residual of polarized fitting is small (0.01). The reason of it should be explained in the text.

Thank you for the comment. The GRASP allows customization of the conditions for stopping iterative fitting and accounts for the noise in the input observations under assumption of that the number of independent observations is significantly larger than the number of retrieved parameters. The situation with very small polarized residuals (< 0.01) likely related with the situations when the observations cover rather narrow range of scattering range and large noise is possible. This is only an explanation that response to the abnormal phenomenon.

Another reviewer made similar observations and recommended that we revise the experiment. So, we have fixed the issue after re-performing the experiment.

Minor Comments:

1) Line 25: Abbreviations should be given full names on their first occurrence.

Thanks for the suggestion. We have fixed this issue now.

2) Line 29-32: Please rephase the sentence.

Thanks for the suggestion. This sentence has been rephrased.

Line 33-36: Compared with MODIS products, the spatial and temporal variations of aerosol could be caught by the DPC with the GRASP/Models, showing a good performance. However, values of AOD were also underestimated by DPC, probably due to over screening high AOD event by cloud mask.

3) Line 221: The reference related Fmask is missing.

Thanks for the suggestion. We have added this reference.

Respond to Reviewer #2

Dear reviewer, thank you for your useful comments. We have carefully analyzed your comments, and replied to your comments point by point and included corresponding modifications in the manuscript. In the following text, your comments are marked in bold italics, our responses are in black, and the modifications in manuscript are shown in blue.

Highlights
- alternate aerosol retrieved by a new satellite sensor with the GRASP algorithm
- investigations of relative relevance of particular sensor data on retrieval accuracy
- comprehensive evaluation

Thank you for the comments. The DPC is the first multi-angle polarized sensor in China and this study is to estimate its performance for aerosol monitor. We hope and believe China's satellite product will be improved with continuous developments and publicly released.

Concerns
- still significant differences in spatial distributions
- with all the extra sensor information … no superiority compared to existing retrievals
- missing absorption and size evaluations, hinder meaningful AOD retrieval assessments

Thank you for the comments. We agree with your concerns. In addition to the use of new retrieval methods, the differences in spatial distribution of AOD is probably also related to other factors including different orbitals, narrower swath width [1] (1850 km of DPC, while that of MODIS is ~2300 km), and cloud mask. Since, only a limited set of DPC data (1/3/2020 to 10/4/2020) is used in our application and thus time span is not large. The AERONET retrieval of complex aerosol optical properties (SSA, etc.) use sky-scanning measurement that are less frequent than direct triple observation of the sun (for only AOD). Therefore, only few matches between DPC and AERONET could be obtained in the range of 25 km/30 min. More importantly, the current study is mainly a preliminary attempt to analyze the DPC data that were strongly compromised by 20% bias… Therefore, our analysis is mainly dedicated to base aerosol parameters such as total AOD, since the retrieval of more detailed properties generally requires very high quality observations. Nonetheless to address the comments we provide the **Figure** below showing preliminary comparisons between daily average SSA and fine-mode AOD from DPC GRASP/Models and AERONET data, as a brief assessment of aerosol absorption and size information. Overall, the result are somewhat comparable to the POLDER-3 GRASP/Models results reported by Chen et al 2020 [2]. Also, as discussed by Chen et al. (2020) it can be noted, that the GRASP/Models was the approach that provided the least accurate retrieval of details aerosol parameters (SSA and AODF) while was the best for AOD.

We hope this illustration can, at least, partially address your concerns. We will make continuous efforts in the future to data quality and usability of Chinese sensors.

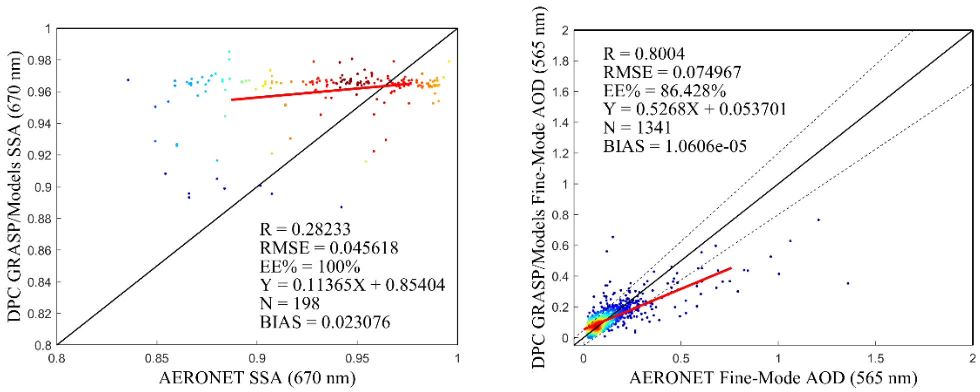

Figure. Comparisons of daily SSA and fine-mode AOD from DPC GRASP/Models and AERONET.

[1] Li, Z., Hou, W., Hong, J., Zheng, F., Luo, D., Wang, J., Gu, X., & Qiao, Y. (2018). Directional Polarimetric Camera (DPC): Monitoring aerosol spectral optical properties over land from satellite observation. Journal of Quantitative Spectroscopy and Radiative Transfer, 218, 21-37, doi:10.1016/j.jqsrt.2018.07.003.

[2] Chen, C., Dubovik, O., Fuertes, D., Litvinov, P., Lapyonok, T., Lopatin, A., Ducos, F., Derimian, Y., Herman, M., Tanré, D., Remer, L.A., Lyapustin, A., Sayer, A.M., Levy, R.C., Hsu, N.C., Descloitres, J., Li, L., Torres, B., Karol, Y., Herrera, M., Herreras, M., Aspetsberger, M., Wanzenboeck, M., Bindreiter, L., Marth, D., Hangler, A., & Federspiel, C. (2020). Validation of GRASP algorithm product from POLDER/PARASOL data and assessment of multi-angular polarimetry potential for aerosol monitoring. Earth System Science Data, 12, 3573-3620, doi:10.5194/essd-12-3573-2020

General comments

A GRASP-based retrieval algorithm is applies to a new Chinese satellite sensor operating since 2018. The Directional Polarimetric Camera (DPC) is a multi-spectral, multi-angle and also polarization sensing instrument to offers a wealth of information about atmosphere and surface. All this information is processed in a statistically optimized GRASP retrieval for a consistent determination of surface and all aerosol properties at cloud free condtions. Retrieval results for AOD are compared to AERONET local statistics and different MODIS versions and indicate general skill. However, AOD spatial distribution samples still leave many questions open. For a more comprehensive AOD comparison/evaluation – especially for comparisons to other satellite data complementary information on aerosol size (e.g. AOD finemode fraction) and absorption e.g. AAOD or even better AAOD attributed to fine and coarse mode) would go a long way. Otherwise, a nice contribution

Thanks for the thoughtful comment. GRASP is the most notable algorithm to this problem, and it has good prospects and has shown convincing results in POLDER-3. Therefore, we decided to follow it. Nonetheless, we agree that obtaining good retrievals of detailed aerosol optical and microphysical need more efforts especially taking into account the current known issues with DPC data availability and quality (20% bias, etc.). Thanks for your understanding, we will continue to work on this in the future.

Specific comments

251 are these effective radii (in um)? Since the size-modes are represented by log-normal

distributions what are mode(-number) radius and std dev (width information)? For dust regions I would allow another super-large (e.g radius ca 6-9um) dust size, as large size mineral dust, if present, will add significant absorption, which otherwise may be incorrectly attributed to finemode aerosol

Thanks for your comments. These are the mode radius rather than effective radius. In the module of GRASP/Optimized, the aerosol size distribution was fit by 5 lognormal bins with mode radii of 0.1, 0.1732, 0.3, 1.0, and 2.9 μm, and mode standard deviations of 0.35, 0.35 ,0.35, 0.5, and 0.5, correspondingly. It should be noted that the contribution of the supper large particles is accounted in those bins. As for the retrieval of details of size concentrations for those super large particles, such retrieval would over ambitious, since the information content in reflected radiation measured from space is rather limited for this ambitious task. This aspect was discussed by Dubovik et al. (2011) and therefore number of parameters of describing the size distribution was significantly reduced for satellite retrieval compare to AERONET retrievals (see also Dubovik et al., 2021).

[1] Dubovik, O., Herman, M., Holdak, A., Lapyonok, T., Tanré, D., Deuzé, J.L., Ducos, F., Sinyuk, A., & Lopatin, A. (2011). Statistically optimized inversion algorithm for enhanced retrieval of aerosol properties from spectral multi-angle polarimetric satellite observations. Atmospheric Measurement Techniques, 4, 975-1018, doi:10.5194/amt-4-975-2011

322 …which is common for aerosol retrieval with most sensors

Thanks for the thoughtful comment. Would you mean general principle for aerosol retrieval? In the forward model of GRASP, surface reflectance is modeled by Ross-Li BRDF and Nadal BPDF, and aerosol is modeled by considering complex optical and microphysical properties. There are no fixed assumptions. To avoid misleading readers, we also revised the text.

Line 268-273

The initial guess of aerosol and surface properties are default in the GRASP software. They are applied to calculate AOD at a global scale. The Ross-Li's model (Li et al. 2001) and the Cox-Munk model (Cox and Munk 1954) were used for modeling radiative (non-polarized) reflectance over land and ocean, respectively, while, the surface polarized reflectance followed the method of Nadal and Bréon (1999). More detailed description can be found in Dubovik et al. (2011),

439 yes as this is kind of a pre-cursur to ESA's upcoming 3MI space sensor

Thanks for your comments. Yes, I learned about the 3MI through the official website. This is a wonderful project that we are looking forward to.

647 show, in addition, the same results side-by side in a log/log scale so info on behavior at low (or most coomon) AOD is better illustrated (the linear fit is less meaningful, as controlled by a few larger values)

Thank you for the suggestions. We agree that presentation in log scale provides some additional inside on the error distribution, therefore we have added such figures. The added figure in the manuscript as shown below. At the same time, we are not sure if this representation will be fully convincing for the readers as we have rarely seen the log scale coordinates before, therefore we keep original figures too.

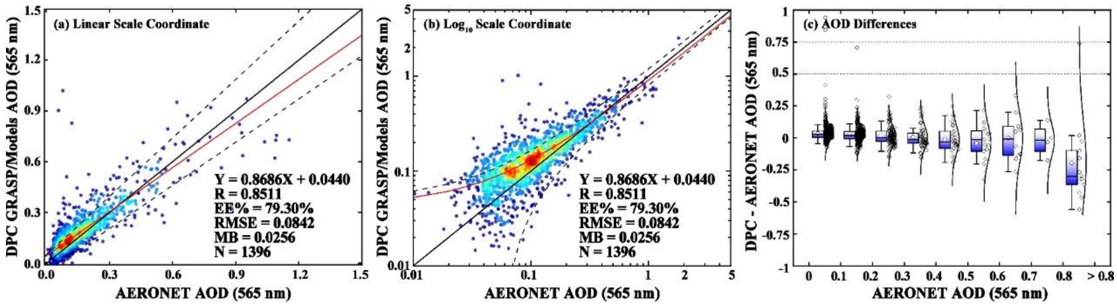

Figure 2. (a) Density scatterplot of AOD retrievals from DPC with the GRASP/Models scheme versus the AERONET observations with a linear coordinate system. **(b)** The density scatterplot with a logarithmic coordinate system. The solid black line is the one to one and the dashed black lines show the ranges of Expected Error. The red solid lines represent the linear regression line; **(c)** Box plots show changes of differences between DPC GRASP/Models and AEROENT with AOD increasing. Diamond marks and curves represent distributions of sample and normal distribution fitting lines, respectively.

651 nice … what about statistics at 1 or 2 (like SLSTR) viewing angles?

Thank you for the suggestions. In this study, we performed cloud screening separately for different angles, since they were not registered at the same time exactly. We further removed those data that only had 1-2 observation angles, in order to prevent the influence of cloud edges. From the principle of GRASP, if new observational errors will not be introduced with increasing number of angles, it is beneficial to the retrieval of complex properties of aerosols. Therefore, it is expected that, unilaterally, the retrieval performance of the retrieval using multiple angles should have benefits compare to use of 1-2 angles is weaker than that of, but it should be enough for only AOD retrieval in GRASP.

658 the 4b figure is so much better to understand than figure 4a! If there would be similar 4b plots for regions this would be perfect.

Thank you for the suggestions. We have added AOD difference figures between DPC GRASP/Models and MODIS DT, DB, and MAIAC products, as shown below. We hope this can add some quantitative statistics to our study.

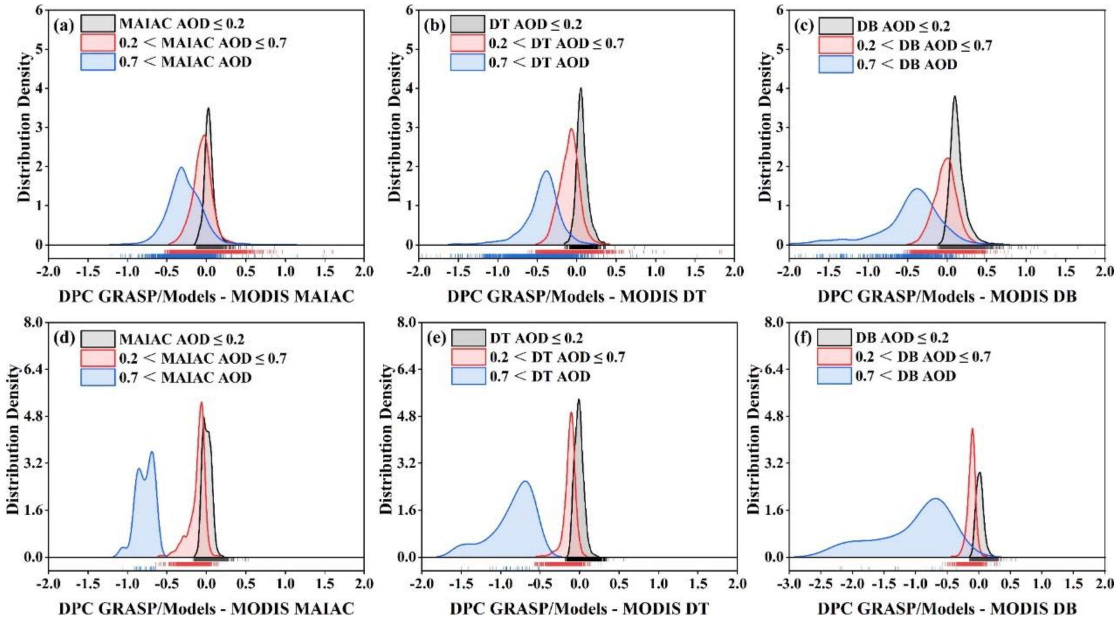

Figure 7. Distribution Density of AOD differences between DPC GRASP/Models and MODIS DT, DB, and MAIAC products at: **(a-c)** Eastern and Southern China with its adjacent sea areas; **(d-e)** Areas of Western Europe including the Atlantic Ocean and the Mediterranean. It is noted that the MODIS DB product only releases terrestrial AOD data.

668 the comparisons to other satellite data is an eye-opener. There ARE differences that need more attention. It is interesting that for E.Asia MODIS DT greater than MODIs DB, while it is the other way around for western Europe. I also would add MISR data (the are available) for the same region I attach a seasonal subset of a general (year-independent) MAC reference, which addresses aerosol amount, size and absorption (not just AOD !) for testing satellite retrievals, to identify major retrieval biases (which can be quickly done, if monthly 1x1 averages are provided).

Thanks for your comments. In terms of spatial analysis, the differences may come from the shorter time span, which is affected by the amount of approved data. Such short-term and large-scale analyses are relatively rare, so we did not want to expand the scope of this study to draw an inappropriate conclusion.

The MISR is a multi-angular detector that can obtain aerosol-scale information. Whereas, our initial investigation indicates that there is a clear systematic underestimation of its AOD in aerosol high loading regions, thus have not considered it for now. In addition, we noticed that a new generation research algorithm optimized for MISR has been proposed (https://amt.copernicus.org/preprints/amt-2022-95/). That study well solves the problem by using a priori MODIS/MAIAC BRDF dataset for high aerosol loading cases, and we are also very much looking forward to its new aerosol product.

Finally, for further complex aerosol optical properties (size and absorption), we calculated them with DPC GRASP/Models as shown following. It must be stated that retrieval of aerosol complex properties depends on to high-quality observations. Since the DPC has large bias, the figure below is just a preliminary result for only reviewing. I used a similar color to your figure for better contrast, and the 10AAOD means ten times of AAOD (10AAOD = 10 × AAOD). I hope this can partially resolve your confusion. The current study is only a preliminary attempt. We will make continuous efforts in the future to data quality and usability of Chinese sensors.

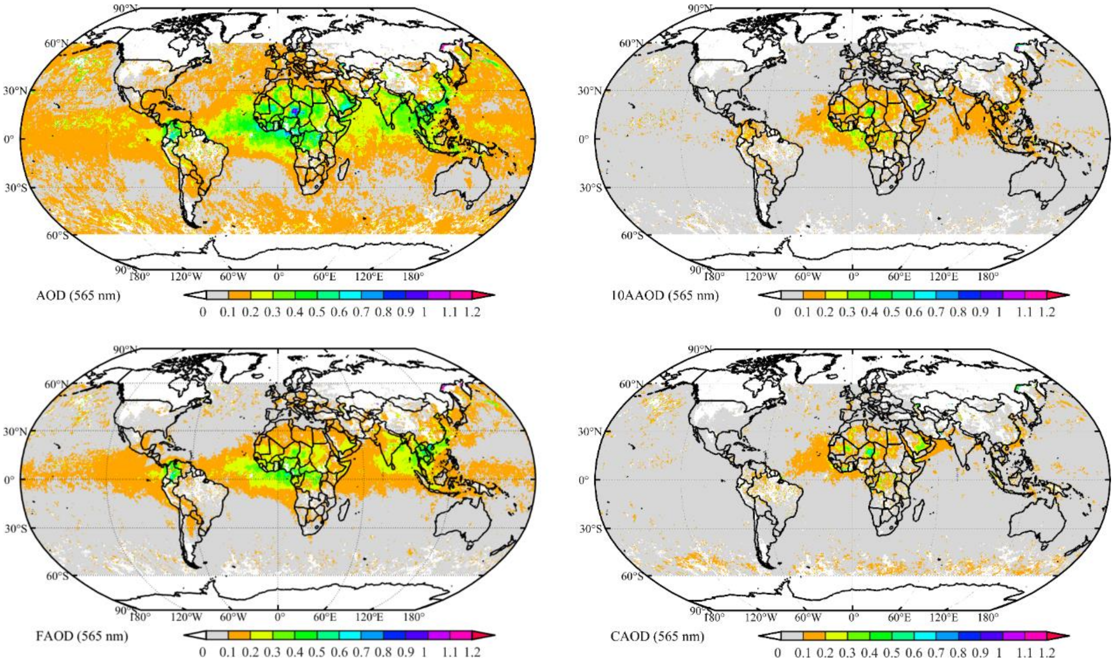

Figure. Distributions of AOD, 10AAOD, Fine-mode AOD, and Coarse-mode AOD retrieved from DPC GRASP/Models during 01/03/2020 to 20/03/2020. I guess the 10AAOD in your figure means ten times of value of AAOD.

Respond to Reviewer #3

Dear reviewer, thank you for your useful comments. We have carefully analyzed your comments, and replied to your comments point by point and included corresponding modifications in the manuscript. In the following text, your comments are marked in bold italics, our responses are in black, and the modifications in manuscript are shown in blue.

The paper outlines an application of the GRASP algorithm to retrieval of aerosol optical depth from observations of the DPC multiangle polarimeter. Results are validated against the AERONET sun-photometer network, from which quality control metrics are devised, and a qualitative comparison is made to three MODIS aerosol products. The performance appears to be consistent with other remotely sensed aerosol products, which is impressive for a relatively new satellite and research team.
While I found the presentation generally good, I was disappointed by the meagre details provided by this manuscript. It would be impossible to replicate the method from this paper alone and the quantitative evaluation covers only AERONET. However, the authors have done a better job than many published works so I expect to see this work in print after some misunderstandings are corrected.

Thank you for the thoughtful comments. The manuscript can provide information about the application of GRASP/Models on the DPC data. Although the DPC data are non-public, the GRASP software is open source code that available at GRASP-OPEN web site (https://www.grasp-sas.com/). The details of GRASP/Models approach are described in several publication, e.g., see Lopatin et al. (2021) and Dubovik et al. (2021)
Thanks for pointing out the mistakes in our manuscript. This will be very helpful for us to improve the quality of the manuscript.

[1] Lopatin, A., Dubovik, O., Fuertes, D., Stenchikov, G., Lapyonok, T., Veselovskii, I., Wienhold, F.G., Shevchenko, I., Hu, Q., & Parajuli, S. (2021). Synergy processing of diverse ground-based remote sensing and in situ data using the GRASP algorithm: applications to radiometer, lidar and radiosonde observations. Atmos. Meas. Tech., 14, 2575-2614, doi:10.5194/amt-14-2575-2021
[2] Dubovik, O., Fuertes, D., Litvinov, P., Lopatin, A., Lapyonok, T., Doubovik, I., Xu, F., Ducos, F., Chen, C., Torres, B., Derimian, Y., Li, L., Herreras-Giralda, M., Herrera, M., Karol, Y., Matar, C., Schuster, G.L., Espinosa, R., Puthukkudy, A., Li, Z., Fischer, J., Preusker, R., Cuesta, J., Kreuter, A., Cede, A., Aspetsberger, M., Marth, D., Bindreiter, L., Hangler, A., Lanzinger, V., Holter, C., & Federspiel, C. (2021). A Comprehensive Description of Multi-Term LSM for Applying Multiple a Priori Constraints in Problems of Atmospheric Remote Sensing: GRASP Algorithm, Concept, and Applications. Frontiers in Remote Sensing, 2:706851, doi:10.3389/frsen.2021.706851

In the following, S means section and L means line number.

- ***At a glance, there is a substantial overlap between this paper and Li et al. 2022 as both apply GRASP to DPC. They evaluate different measurands and only share two authors, but my experience is that the AOD products discussed here are a by-product of the aerosol type***

products discussed there. The manuscript before me certainly provides additional information and I am not questioning the logic in publishing the projects separately. However, there must be more clarification of the relationship between the teams, either acknowledging how their work has complemented each other (e.g. I would hope that their determination of aerosol type provided the inputs to this method) or explaining why it was necessary to make separate implementations of the same code (to assist future GRASP users in determining which to use)?

Thank you for the comment. Are you referring to the article by Lei Li et al [1] published on the *Atmospheric Research* in March 2022? Our study is completely independent of them. This study was independently initiated by Wuhan University and completed with the help from GRASP team (Dr. Chen and Prof. Dubovik) and DPC team (Dr. Hong). Authors are selected in accordance with actual contributions. In fact, Li's article is more like a case study of pollution events in eastern China without any actual quantitative assessment, neither AOD nor type products. By contrast, our study is a quantitative assessment of DPC/GRASP AOD on a global scale according to AERONET. It's not a same story for our perspective. In addition, Dr. Hong is one of the heads of DPC, mainly responsible for the calibration work, and therefore, we didn't rush our experiments until we fully figured out the DPC calibration performance. Whereas, in the meantime, a study of a comprehensive assessment of radiation measurements of DPC was published on *Remote Sensing* in March 2022 [2]. It depicted large uncertainties of the DPC signals (can be up to 20%) and provided a correction method. We don't know whether Li's study have taken these into account. Therefore, although I think his research is good, we did not benefit from research extensively in our manuscript.

There is a significant difference of Lei Li et al [1] and current studies. Lei Li et al [1] implemented GRASP/Components approach while in present studies we used GRASP/Models approach. While GRASP/Components approach retrieved more parameters and provides more extensive set of aerosol parameters, GRASP/Models approach uses more constraints on retrieved aerosol and shows very stable and convincing performance for total AOD that is superior over other GRASP approaches (e.g. see Chen et al. (2020) and Dubovik et al. (2021)). Therefore, knowing the issues with high DPC uncertainties we have chosen GRASP/Models approach and focused our study on the analysis of AOD retrievals.

[1] Li, L., Che, H., Zhang, X., Chen, C., Chen, X., Gui, K., Liang, Y., Wang, F., Derimian, Y., Fuertes, D., Dubovik, O., Zheng, Y., Zhang, L., Guo, B., Wang, Y., & Zhang, X. (2022). A satellite-measured view of aerosol component content and optical property in a haze-polluted case over North China Plain. Atmospheric Research, 266, 105958 (DOI: 10.1016/j.atmosres.2021.105958)

[2] Zhu, S., Li, Z., Qie, L., Xu, H., Ge, B., Xie, Y., Qiao, R., Xie, Y., Hong, J., Meng, B., Tu, B., & Chen, F. (2022). In-Flight Relative Radiometric Calibration of a Wide Field of View Directional Polarimetric Camera Based on the Rayleigh Scattering over Ocean. Remote Sensing, 14 (DOI: 10.3390/rs14051211)

[3] Levy, R.C., Remer, L.A., & Dubovik, O. (2007). Global aerosol optical properties and application to Moderate Resolution Imaging Spectroradiometer aerosol retrieval over land. Journal of Geophysical Research Atmospheres, 112 (DOI: 10.1029/2006JD007815)

[4] Chen, C., Dubovik, O., Fuertes, D., Litvinov, P., Lapyonok, T., Lopatin, A., Ducos, F., Derimian, Y., Herman, M., Tanré, D., Remer, L.A., Lyapustin, A., Sayer, A.M., Levy, R.C., Hsu, N.C., Descloitres, J., Li, L., Torres, B.,

Karol, Y., Herrera, M., Herreras, M., Aspetsberger, M., Wanzenboeck, M., Bindreiter, L., Marth, D., Hangler, A., & Federspiel, C. (2020). Validation of GRASP algorithm product from POLDER/PARASOL data and assessment of multi-angular polarimetry potential for aerosol monitoring. Earth System Science Data, 12, 3573-3620 (DOI: 10.5194/essd-12-3573-2020)

[5] Dubovik, O., Fuertes, D., Litvinov, P., Lopatin, A., Lapyonok, T., Doubovik, I., Xu, F., Ducos, F., Chen, C., Torres, B., Derimian, Y., Li, L., Herreras-Giralda, M., Herrera, M., Karol, Y., Matar, C., Schuster, G.L., Espinosa, R., Puthukkudy, A., Li, Z., Fischer, J., Preusker, R., Cuesta, J., Kreuter, A., Cede, A., Aspetsberger, M., Marth, D., Bindreiter, L., Hangler, A., Lanzinger, V., Holter, C., & Federspiel, C. (2021). A Comprehensive Description of Multi-Term LSM for Applying Multiple a Priori Constraints in Problems of Atmospheric Remote Sensing: GRASP Algorithm, Concept, and Applications. Frontiers in Remote Sensing, 2:706851, doi:10.3389/frsen.2021.706851

- ***Throughout the paper the authors report Expect Error (EE%), being the number of retrieved values falling within some range of the validation value, and comment positively when these increases. Putting aside the fact that the authors never define the term, nor state the envelope they use, this misunderstands the meaning of an error envelope. The MODIS error envelope is an estimate of a normally distributed error derived from comparison to validation data. As such, only 68% of data should fall within the error envelope (see "one sigma confidence interval"). Achieving a higher EE% does not mean the data is "better", merely that the EE overestimated the uncertainty in the circumstances considered. Ideally, the authors would estimate their own error envelope, which would presumably be narrower than that of MODIS. At a minimum, though, the authors must revise the language to express that the ideal EE% is 68%. (Also, Expected Error would be more grammatically correct.)***

Thank you for the comment. According to your correction, we are fully aware that existing expression of EE% in the manuscript can cause some problems and misunderstandings. Therefore, we modified it and added an explanation based on your suggestion. In addition, we would like to clarify that the relatively high EE% in DPC/GRASP AOD is only used to show the good performance of DPC in our manuscript. We do not expect (or do not think) that the EE% can be used alone to evaluate the performance of AOD products. The specific modification is as follow:

Line 288-296:

Linear regression, correlation coefficient (R), Root Mean Square Error (RMSE), Mean Bias (MB), percentage falling into Expected Error **(EE%, ±(0.05+0.15*AOD))**, and matching Number (N) were also calculated. Among them, the EE% is selected in accordance with the MODIS error envelop and **the ideal EE% is ~68% under assumption of normal distribution within one sigma confidence interval**. Therefore, the EE can be used to estimate approximately the accuracy MODIS AOD. Overall, the DPC GRASP/Models AOD matches the AERONET observations with an R of 0.8511, a MB of 0.0256, and a RMSE of 0.0842, showing good performance without any quality control. Nearly 80% of the GRASP/Models AOD retrievals fall within the Expected Error bounds, **revealing that the error envelop of DPC is probably narrower than that of MODIS**.

- ***While being clear that I don't expect the authors to change anything in the paper as they follow common and widespread practice, I will point out that the evaluation provided does not actually assess the accuracy of their retrievals. It assesses the accuracy of 30min/25km***

averages of their retrievals. Thus, the variability shown is a lower bound for the method's performance. This is clearly demonstrated in Fig.3(d), where accuracy improves as more observations are aggregated.

Thank you for the thoughtful comments. Yes, as you point out, the accuracy improves with more observations aggregated. But here is one more thing to clarify. The "number of averaged pixels" is also an indicator for GRASP, because the GRASP takes into account the surrounding pixels in the retrieval of aerosols. The finding that "accuracy improves as more observations are aggregated" also suggests that multi-pixel retrieval have better performance than sing-pixel retrieval especially for GRASP.

- ***The MODIS Dark Target, Deep Blue and MAIAC products are widely used, so I understand why the authors compare to them. But why do they not compare to MISR (or another polarimeter), which would provide a like-for-like comparison to another multiangle retrieval and demonstrate the relative merits of the GRASP method?***

Thank you for the comment. Our main purpose is to study (or assess) the DPC rather than the GRASP, while the GRASP is a well-developed and flexible algorithm that has been applied on many instruments. I know there are several multi-angle or polarization payloads in orbit, such as the SGLI/GCOM-C (Japan), but it is difficult to access to their products. For MISR, our initial investigation indicates that there is a clear systematic underestimation of its AOD in aerosol high loading regions, thus we do not use them either. In addition, we noticed that a new generation algorithm optimized for MISR has been proposed (https://amt.copernicus.org/preprints/amt-2022-95/). That study well solves the problem by using MODIS/MAIAC BRDF dataset, and we also look forward to its new aerosol product.

- ***I am more disappointed that, given the number of satellites it has been applied to, there is no comparison to another implementation of GRASP. That would provide valuable insight into the relative performance of the DPC sensor independent of retrieval method and assumptions.***

Thank you for the comment. I am sorry for making you feel that. The main purpose is to study DPC in our research. To be honest, we have tested several implementations of GRASP on DPC observations, and the GRASP/Models module was select after balancing the performance and calculation speed. For instance, for an implementation that uses 16 bins to fit the aerosol volume size distribution without any optimization (as case recorded in GRASP software), a unit with 300 pixels can take more than an hour to compute (2.5 GHz Xeon CPU). Therefore, only the results from GRASP/Models approach are present in our manuscript.

- ***S2.3) Please be more precise as to the data used. Do you use every AERONET site in the record or do you exclude some? Do you report every collocation or do you exclude some? Do you use Level 1.5 or Level 2.0 as using both would be extremely foolish?***

Thank you for the comment. In the original results, we used all the sites that matched DPC data, including Level 1.5 and Level 2.0. Whereas, to avoid being foolish :), we revised the study and only used Level 2.0 data in the revised manuscript. All 178 sites with available Level 2.0 AOD during the study period participated in the validation and we also re-evaluated the results. The specific modification is as follow:

Line 156-157:

The AOD data used for validation were acquired from all **178 AERONET sites** with available Level 2.0 AOD products during the study period, which have been cloud-screened and quality controlled.

- ***L215-7) I do not know what you mean by 'absolute value of average relative deviations'. An equation would be clearer.***

Thank you for the comment. We have added two equations for clarification. When the value of whiteness test is greater than 0.7, the pixel is considered to be cloudy.

Line 219-223:

$$MeanVis = (Band_1 + Band_2 + Band_3)/3 \quad (2)$$

$$Whiteness\ Test = \sum_{i=1}^{3} |(Band_1 - MeanVis)/MeanVis| > 0.7 \quad (3)$$

Where, $Band_1$, $Band_2$, and $Band_3$ are reflectance in red, green, and blue bands received by satellite at top of the atmosphere, respectively. Corresponding to the DPC, they are 490, 565, and 670 nm, respectively.

- ***S3.3) You don't appear to do any cloud filtering before averaging. Why not, given how common such approaches are in other aerosol retrievals?***

Thank you for the comment. We have done the cloud screening before averaging. The cloud screening is done after radiometric calibration and it precedes all other retrieval operations.

- ***L236) The text states that the retrieval unit is 3x3 but Fig.1 shows a 5x5 unit. I appreciate that the larger cube helps illustrate the inclusion of different surfaces types in a single retrieval but please clarify what, precisely, is being done.***

Thank you for the comment. There seems to be misunderstanding. The 3x3 averaged was performed on the raw DPC data, to reduce the amount of data and improve the signal-to-noise ratio of the aerosol signal and make the spatial resolution close to that of the MODIS product. This means that in retrieval, 9 DPC pixels were averaged into one pixel in a retrieval unit. In other words, this 3x3 represents a down-sampling process. Whereas, the 5x5xNT (number of time layers) in the Fig. 1 means the scale of retrieval unit which was used for GRASP multi-pixel retrieval in our study. For example, assuming that the AOD of an AERONET site is to be calculated, then we can take it as a center and select 5x5 (total 25) pixels around this site to put into the GRASP model. In GRASP retrieval (or iteration), the loss function needs to take a global minimum for these a group of pixels. In this way, the multi-pixel retrieval is achieved, instead of the well-known pixel-by-pixel (single-pixel) retrieval. In our validation activity, we used the 5x5 window for aggregation, while in the POLDER-3 validation [1], it used 3x3 for land and 9x9 for ocean, while for the retrieval it used

2x2xNT. This means that the scale of retrieval unit can be changed as needed. A large scale of retrieval unit usually reveals that the more surrounding pixel information is considered, but the more memory is needed.

[1] Chen, C., Dubovik, O., Fuertes, D., Litvinov, P., Lapyonok, T., Lopatin, A., Ducos, F., Derimian, Y., Herman, M., Tanré, D., Remer, L.A., Lyapustin, A., Sayer, A.M., Levy, R.C., Hsu, N.C., Descloitres, J., Li, L., Torres, B., Karol, Y., Herrera, M., Herreras, M., Aspetsberger, M., Wanzenboeck, M., Bindreiter, L., Marth, D., Hangler, A., & Federspiel, C. (2020). Validation of GRASP algorithm product from POLDER/PARASOL data and assessment of multi-angular polarimetry potential for aerosol monitoring. Earth System Science Data, 12, 3573-3620 (DOI: 10.5194/essd-12-3573-2020)

- ***Fig.2) I strongly agree with Dr. Kinne that this figure should be shown on a logarithmic scale. doi:10.5194/acp-19-15023-2019 provides compelling evidence that linear averaging of AOD provides misleading conclusions.***

Thank you for the comment. I agree with you and so I have added the density scatterplots and showed them on logarithmic scale. As Prof. Sayer points out in 10.5194/acp-19-15023-2019 that AOD is often distributed close to log-normally on large scales, the usage of the logarithmic coordinate system can display the scatter plot of AOD more clearly. Meanwhile, we keep the plot using linear scale, which also provide useful information especially for high AOD cases.

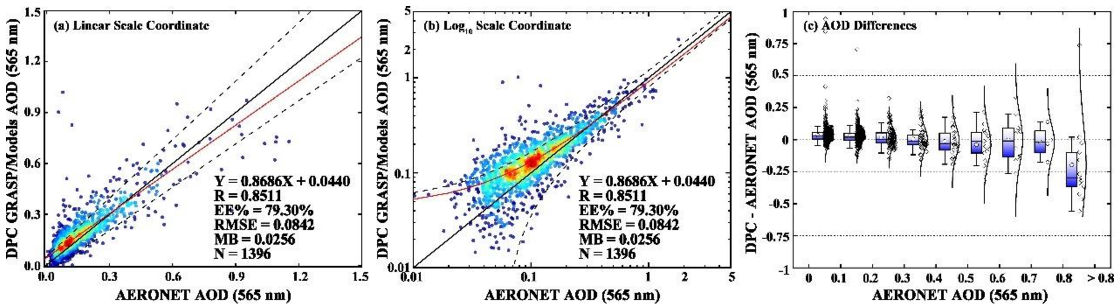

Figure 2. (a) Density scatterplot of AOD retrievals from DPC with the GRASP/Models scheme versus the AERONET observations with a linear coordinate system. **(b)** The density scatterplot with a logarithmic coordinate system. The solid black line is the one to one and the dashed black lines show the ranges of Expected Error. The red solid lines represent the linear regression line; **(c)** Box plots show changes of differences between DPC GRASP/Models and AEROENT with AOD increasing. Diamond marks and curves represent distributions of sample and normal distribution fitting lines, respectively.

- ***L284) I disagree that Fig.2 shows that you underestimate AOD in high loading circumstances. I read that plot as showing an underestimate of AOD in typical circumstances (as the red blob is above the black line; see also the grey curve of Fig.4b). Your best-fit line has a gradient less than one largely because it's going through the peak of the distribution around 0.1 and towards the handful of points around 1.2.***

Thank you for the comment. Yes, linear regression line may lead a wrong conclusion as you point out. Therefore, to further explain, we added a figure to show how the bias changes with the AOD increasing, as **Figure 2(c)** mentioned above. Despite the limited sample (12 points), it clearly shows that the DPC AOD is underestimated when the AERONET AOD is greater than 0.8. We have made corresponding changes in the text.

Line 297-300

This means that under heavy aerosol loading, the DPC/GRASP probably underestimate the AOD. More details are presented in **Figure 2c**. It is found the lower slope of linear regression is mainly controlled by several points which have larger AOD (> 0.8). By contrast, when AOD is less than 0.8, the retrieval is stable.

Line 329-333

Figure 4c displayed the change of differences between DPC and AEROENT AOD. The underestimations when AOD > 0.8 were not found to be restrained by the quality control. A possible reason is that an overly restrictive cloud mask can remove aerosol pixels during heavy pollution. In addition, the negative drift after the launch of the DPC may also be the reason, if it is not fully corrected.

- ***L286) There are numerous sources of error in any AOD retrieval and I would be surprised if the aging of the detector was the primary one.***

Thank you for the comments. Our research is applying existing methods to a new sensor. It means we are more inclined to find the reason from the DPC hardware when analyzing the error, because we have had a preliminary understanding of the performance of GRASP/Models from other previous studies. In addition, more importantly, the DPC has a severe negative drift in the radiation calibration results after launch. This is why we used additional correction coefficients in the study. If we do not use the additional correction coefficients, the most immediate result is a significant underestimation of AOD. Here we refer a retrieval case by Prof. Zhengqiang Li's team, as following **Figure** (http://www.sonet.ac.cn/yjdt/html/?200.html=) [1]. Therefore, when there is an underestimation in our results, our inference is the issue of DPC radiometric calibration. The possible cause of this negative drift is the aging of the instrument (probably the battery). While, in order not to cause misunderstandings by readers, we have also revised this sentence.

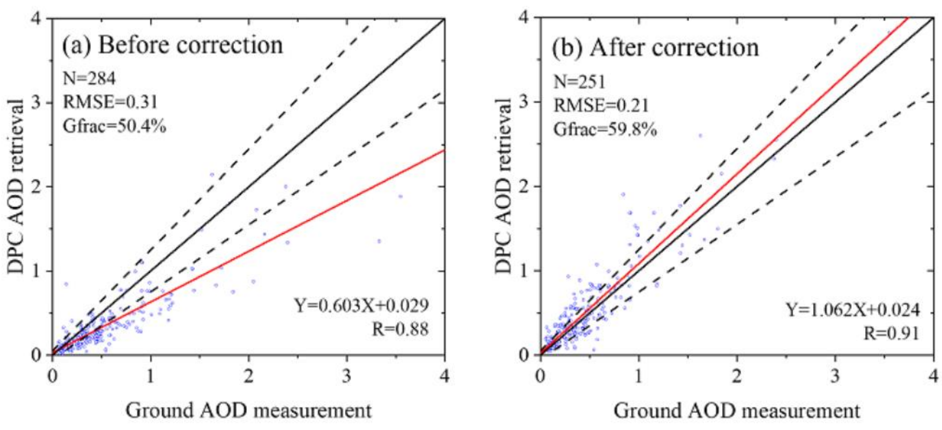

Figure. (a) AOD retrievals **without** the additional correction coefficients; **(b)** AOD retrievals **with** the additional correction coefficients.

[1] Zhu, S., Li, Z., Qie, L., Xu, H., Ge, B., Xie, Y., Qiao, R., Xie, Y., Hong, J., Meng, B., Tu, B., & Chen, F. (2022). In-Flight Relative Radiometric Calibration of a Wide Field of View Directional Polarimetric Camera Based on the Rayleigh Scattering over Ocean. Remote Sensing, 14 (DOI: 10.3390/rs14051211)

Line 329-333

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- ***L297) On L255, you said that the method of external mixtures was under testing, which I took to mean "an experimental mode that will eventually be available". The text here implies that that is the mode you used. Please clarify what was done.***

Thank you for the comments. In this study, the GRASP/Models is applied on the DPC data and it is a first try based on the implementation of POLDER GRASP/Models application. The current version of GRASP/Models already has good performance and has been tested on POLDER-3 [1] and DPC (our study). However, it still could improve in the setting of coarse particle optical properties, definition of models etc. So, the sentence there means that the GRASP-SAS will continue to improving the GRASP/Models approach, and the current version in our study is not final.

[1] Chen, C., Dubovik, O., Fuertes, D., Litvinov, P., Lapyonok, T., Lopatin, A., Ducos, F., Derimian, Y., Herman, M., Tanré, D., Remer, L.A., Lyapustin, A., Sayer, A.M., Levy, R.C., Hsu, N.C., Descloitres, J., Li, L., Torres, B., Karol, Y., Herrera, M., Herreras, M., Aspetsberger, M., Wanzenboeck, M., Bindreiter, L., Marth, D., Hangler, A., & Federspiel, C. (2020). Validation of GRASP algorithm product from POLDER/PARASOL data and assessment of multi-angular polarimetry potential for aerosol monitoring. Earth System Science Data, 12, 3573-3620 (DOI: 10.5194/essd-12-3573-2020)

- ***L308) The retrieval residuals should conform to some distribution, such that very small values are not unexpected. Why is the polarized component different, requiring the exclusion of small residuals? My gut instinct would be a systematic bias in the observations or something about the representation of Rayleigh scattering in the forward model.***

Thank you for the comments. The GRASP allows customization of the conditions for stopping iterative fitting and accounts for the noise in the input observations under assumption of that the number of independent observations is significantly larger than the number of retrieved parameters. The situation with very small polarized residuals (< 0.01) likely related with the situations when the observations cover rather narrow range of scattering range and large noise is possible. This is only an explanation that response to the abnormal phenomenon.
After revision (replacing combination of Level 1.5 and Level 2.0 with Level 2.0 for AERONET), the abnormal phenomenon (AOD results with larger biases but the polarized fitting residuals were lower) has been alleviated. Thus, we removed this requirement to perform validation (polarized

fitting residual < 0.01). In addition, distributions of fitting residual are shown as following **Figure**.

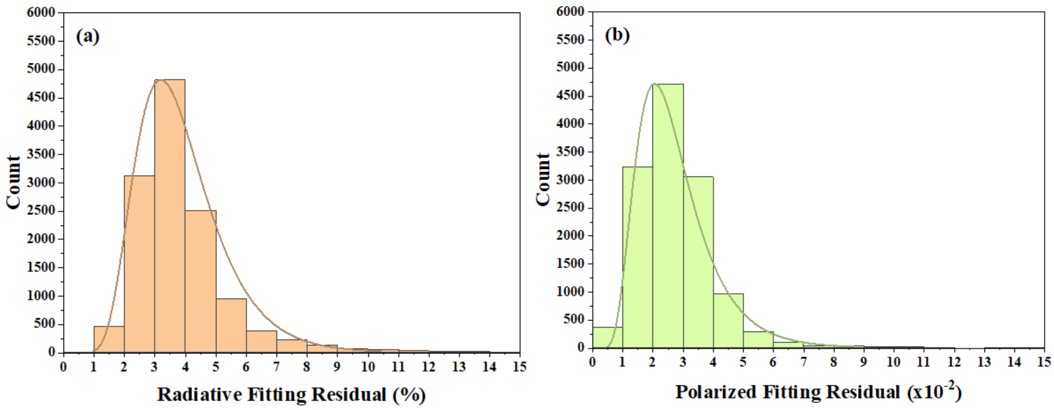

Figure. (a) Distribution of radiative fitting residual; **(b)** Distribution of polarized fitting residual. The curves are log-normally fitting lines.

Line 322-324:

Retrieval is considered low quality if any of the following conditions are met: 1) Pixels with SCA > 150; 2) number of averaged pixels < 4; 3) length of timesteps < 5; 4) non-polarized fitting residual > 8%; 5) polarized fitting residual > 0.06.

- ***Fig.6) This is an entirely qualitative comparison. There's nothing necessarily wrong with that, but I feel a page of description is inappropriate for two hand-picked scenes that cannot represented general performance. Perhaps the figure could appear at the start of the section as an illustration of the approach? Also, I feel the authors have failed to mention the most important feature of this diagram: their method exhibits minimal land-sea contrast compared to others. This is a long-standing advantage of GRASP retrievals and limitation of other methods that is not widely acknowledged.***

Thank you for the comments. To add a quantitative evaluation, differences between DPC GRASP and other MODIS aerosol products were calculated as **Figure 7** in the revised manuscript (also showing as follow). From this figure, the DPC GRASP/Models AOD is still different from other MODIS products that cannot be ignored. The most obvious feature is the underestimation of AOD when the aerosol loading is heavy.
Also, we agree with you that the GRASP has the smallest land-sea contrast and we added some sentences to describe this feature in the revised manuscript.

Line 386-389

Compared with single pixel-based retrieval algorithm (such as DT and DB), the GRASP and MAIAC considered more temporal and spatial information of aerosol and surface parameters. And benefit from the consistency of all assumptions (regarding aerosol and a priori constrains), the DPC GRASP exhibits minimal land-sea contrast.

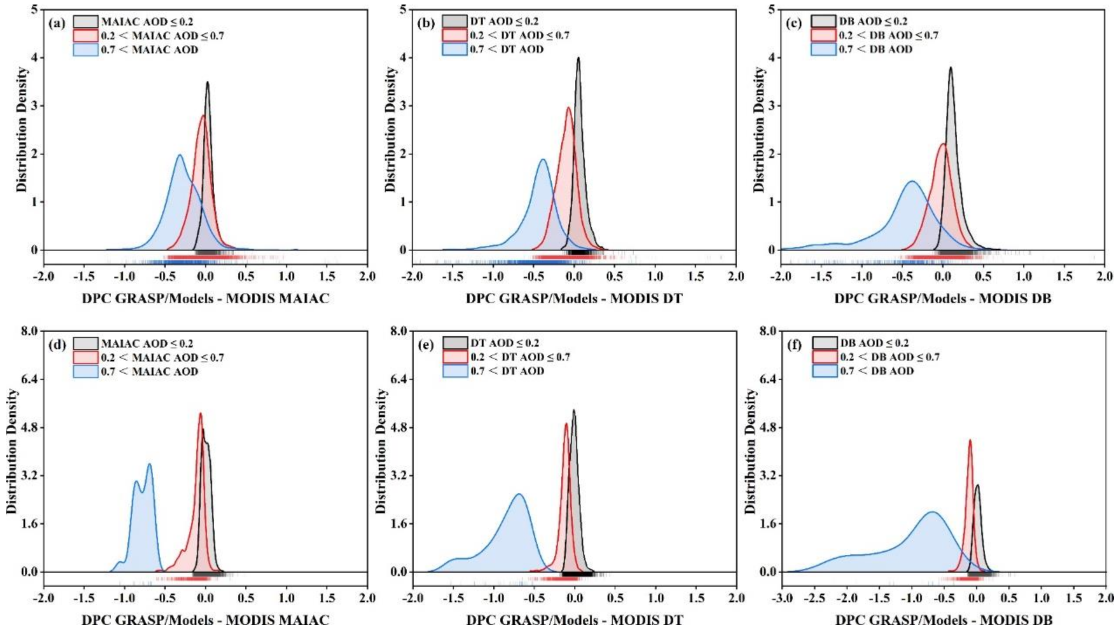

Figure 7. Distribution Density of AOD differences between DPC GRASP/Models and MODIS DT, DB, and MAIAC products at: **(a-c)** Eastern and Southern China with its adjacent sea areas; **(d-f)** Areas of Western Europe including the Atlantic Ocean and the Mediterranean. It is noted that the MODIS DB product only releases terrestrial AOD data.

- ***Fig.7) While I appreciate an example of the performance over time, I do not like the units chosen (mean error ratio). As the text describes, MER can decrease both because a method has large, but complementary, errors; because the error envelope increases; or because different time steps present more/less difficult retrieval conditions. Further, L387 is not strictly correct as a lower MER can be achieved by a lower Error Envelope, which would happen if one method retrieves larger values than the other. More generally, I'm curious why the authors use normalised mean square error throughout the paper (without specifying by what the error is normalised; different communities would expect the retrieved value or the EE) rather than the more common root-mean square error?***

Thank you for the comment. Initially, the usage of normalized mean square error (NMSE) rather than the more common root-mean square error (RMSE) is in order to reflect the DPC retrieval performance when the AOD is small. But we found that a better approach is to use a logarithmic scale, as you suggested above. So, in the revised version, we changed the NMSE back to RMSE and re-drew the **Figure 8** as following. From this figure, the DPC GRASP/Models AOD shows a good performance with lower average daily RMSE. This is also in accordance with the higher EE%, which reveals that the error envelop of DPC GRASP/Models is probably narrower than that of MODIS. The corresponding parts of the text have also been revised, as follows:

Line 407-419

From the **Figure 8**, it was found that the time series of AOD from DPC GRASP/Models had a good matching with the AERONET AOD. The values of RMSE were ~0.06 and stable before 87th day. While the reason of relatively large RMSE (~0.12) around 90th day is presumed to be heavy aerosol loading conditions, as the DPC GRASP/Models would underestimate AOD under this situation. The similar temporary rapid increases in RMSE were also found in MODIS products, such as the 80th day of the DT, the 85th day of the DB, and 98th day of the MAIAC. This reflects the time instability of algorithms. In addition, the lowest daily averaged RMSE was found in DPC GRASP/Models with value of 0.0663, and then MODIS DT (0.0863) and MODIS DB (0.0913). The low RMSE of DPC may be due to it ignoring some high value AODs. It is worth noting that the same parameter scheme (including start points and constraints) was applied globally in the GRASP/Models. Therefore, the difference in aerosol optical properties and spatial-temporal heterogeneity in different regions may be not considered appropriately.

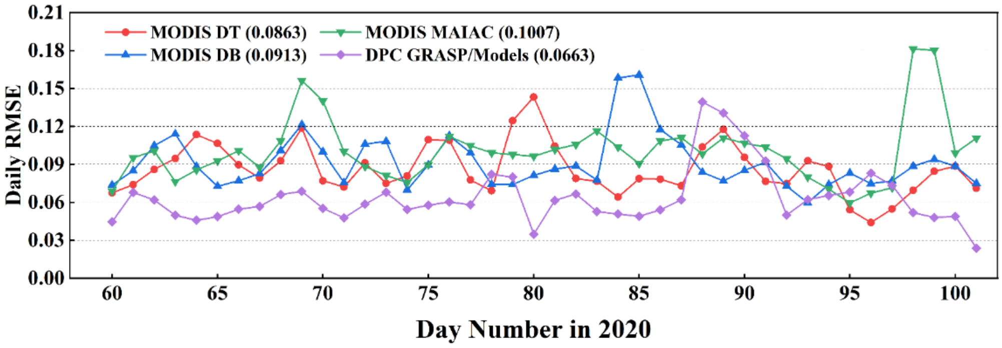

Figure 8. Time series of daily RMSE for the selected AERONET stations during March and April of 2020. The number in brackets are averaged values of daily RMSE.

- ***Some more minor comments:***
-
- ***L42) D'Almeida 1991 is a strange reference here, considering it's a microbiology paper.***

Thank you for the comment. I guess there were some problems inserting the reference, but now we have fixed it.

- ***L126) By "normalized radiation", do you mean "reflectance"?***

Thank you for the comment.. Yes, the “normalized radiation” is “reflectance” received by satellite sensor (at top of the atmosphere).

- ***L147) Please be specific what is meant by "highest quality" as different fields mean different things by it.***

Thanks for pointing out this. We have revised this section and specified the data selection, as following.

Line 147-150

The corrected AOD (quality flag = 3) on land and average AOD (quality flag = 1,2,3) on the ocean are selected in the DT products. The best estimated AOD (quality flag = 2,3) is selected in the DB products. The best quality AOD (QA AOD = 0000) is selected in the MAIAC products.

- ***L156) These are common collocation criteria, and I am not asking you to change anything***

here, but you may find it beneficial to read the series of papers Nick Schutgens has published on the best strategy to collocate different aerosol datasets, such as doi:10.5194/acp-20-12431-2020, 10.5194/acp-2015-973 and 10.5194/acp-16-1065-2016.

Thanks for these instructive comments and information. It's very useful and brings new ideas of collocation and present the validation results, such as Taylor diagram.

- ***L187) I disagree. It is entirely feasible to create a look-up-table-based method that integrates different instruments as, if you have an module that perform a calculation, it is possible to build a look-up table from it. The advantages of GRASP lie in its detailed radiative transfer simulations and multipixel approach. If you replace 'traditional look-up table-based methods' with 'most popular retrieval methods' I no longer have a problem with the sentence.***

Thank you for the comment. We have revised this sentence as your suggestion.

Line 189-191

This avoids that the most popular look-up table-based methods are difficult to apply to each other, due to the limitations of different sensor channel and characteristic.

- ***L230) How often does DOLP>1 happen? Unless it's extremely rare, this filtering feels like it would introduce a low bias into that value.***

Thank you for the comment. The DOLP means ratio of linearly polarized light to total light. When the DOLP is 0, it indicates that the light is unpolarized (such as sunlight), when the DOLP is 0 to 1, it indicates that the light is partially linearly polarized, and when the DOLP is 1, it indicates that the light is fully linearly polarized. Therefore, the DOLP must be less than 1 theocratically. It is also rare that the DOLP is greater than 1 on the DPC, which may be caused by the calibration error of the Stokes parameters.

- ***L259-60) Does 'exponential distribution' mean that your vertical levels are spaced exponentially, such that they are roughly equally spaced in pressure?***

Thank you for the comment. The 'exponential distribution' here is relative to several other common vertical distributions of aerosols, such as Gaussian or single layer distribution. It is usually used as a priori assumption on the vertical height of the aerosol, when retrieving aerosols [1]. Because GRASP allows retrieval of parameters related to the vertical height of aerosols, and so this sentence is used to illustrate what vertical assumptions we used. So, in the AOD retrieval, this is not related to the pressure.

[1] Wu, Y., de Graaf, M., & Menenti, M. (2017). The impact of aerosol vertical distribution on aerosol optical depth retrieval using CALIPSO and MODIS data: Case study over dust and smoke regions. Journal of Geophysical Research: Atmospheres, 122, 8801-8815, doi:10.1002/2016jd026355

- ***L262) "General principles" is far too generic a description. Either remove it because the text that follows elaborates or explain what you mean.***

Thank you for the comment. We have revised this sentence as you marked in the text.

- ***Fig.3) Please reproduce this figure so the text is a similar size to that in the figure's caption.***

Thank you for the comment.. We have re-draw this figure and increase the font size.

- ***L296) I think it would be clearer to refer to 'timesteps' rather than 'retrieval units'.***

Thank you for the comment.. We revised and used the “timesteps” instead of the “the length of retrieval units” to express the number of observations in the time dimension.

- ***L311) Also on L425. I think you've gotten the direction of the inequality wrong for the residuals, as it currently implies you remove high scattering angle and middline polarized residual. I also think you mean 'or' rather than 'and' as very few points will satisfy all of those conditions simultaneously.***

Thanks for pointing out mistakes. This probably came from editing. We've fixed it now.

Line 322-324

Retrieval is considered low quality if any of the following conditions are met: 1) Pixels with SCA > 150; 2) number of averaged pixels < 4; 3) non-polarized fitting residual > 8%; 4) polarized fitting residual > 0.06.

- ***L414) It will certainly occupy an important position in China. The impact on the rest of the world will depend on the availability of the data.***

Thank you for the comment. We hope and believe that the disclosure and release system of China's satellite data will be improved.

- ***L671) While appreciating that the authors likely have little control over it, I see no reason for the nine-dotted line to appear in this plot as it is a political, rather than physical, boundary.***

Thank you for the comment. We have deleted the related description.

- ***I attach an annotated PDF with typographic corrections I hope will be of use. They are largely verb tenses and use of 'the', which I certainly couldn't do accurately in another language. Red lines indicate text to delete while yellow highlight is for word replacement or insertion. As these were done by hand on a tablet, they do not cover precisely the words affected and all capitalisation in my comments should be ignored. Also, many of the citations either lack or incorrectly state the page number of the paper. If the authors have the time, it***

would be a massive improvement to include the DOIs of papers as this simplifies finding a paper.

Dear reviewer, we are grateful that you can make such careful revisions, which we have rarely received before. Based on your suggestions, we have revised the text one by one, and added page numbers and DOI information for the references. It is no doubt that your comments are very important to us. Thanks for your review.