**Reviewer1**

The paper presents a validation of several implementations of the GRASP algorithm for the retrieval of aerosol optical depth (AOD), single-scattering albedo (SSA), Angstrom exponent, and surface bidirectional reflectance function (BRDF). The focus is two synergistic retrievals: one combining TROPOMI and OLCI with a second scheme further including AHI. Their results are validated against AERONET, demonstrating that the 3-sensor approach out-performs the 2-sensor one, which itself out-performs single-sensor analyses. A less detailed comparison of BRDF is presented against MODIS.
This work is the sort of validation study that every algorithm team should publish from time to time. It should be accepted after some minor corrections.

Response:
We sincerely appreciate the reviewer for very valuable feedback, comments, and corrections on the English language of the manuscript. The main purpose of the paper is to present the physical basis and concept of the developed synergetic approach, which was implemented into the GRASP algorithm. The validation results were presented only to prove the concept and to demonstrate the new possibilities of the SYREMIS/GRASP approach. To emphasize the main purpose of the paper, the paper was modified correspondingly.

- The figure captions are insufficient. Given GRASP's popularity, this might be the first time someone ever encounters an aerosol validation and we should try to be welcoming. Those that begin "The same as" are fine, but the remainder assume the reader is familiar with the standard validation plots of aerosol retrieval methods. Fig. 2 should explain (i) what the annotation provides, (ii) what the grey envelope denotes, (iii) what the colour represents, (iv) what AERONET is given that it's never introduced or cited.
    - I also remind the authors that use of the rainbow colour map is discouraged for reasons eloquently explained in doi:10.1038/s41467-020-19160-7.

**Response:**
Many thanks for pointing this out. We have updated the validation plots throughout the manuscript. Fig. 4 caption and Section 2.4 explain all the details of the scatter plot and histograms: the correlation statistics in the legends, the grey envelope, the color of each data point, AERONET reference, etc. The x-axis and y-axis scales of the scatter plots and the x-axis width of the histograms are adjusted for better visualization.

- For a paper that sets out to "discuss the physical basis and concept" of its retrievals, there is minimal description of the actual algorithm beyond Tables 2-4. It would be impossible for a PhD student to implement the technique introduced from this paper alone. I know that the GRASP method is extremely thoroughly documented, and that those papers are already cited, but the authors could provide slightly more guidance to the unfamiliar reader in the paragraph of lines 113-119. Something like, "An outline of the general infrastructure for GRASP is provided in XXX, with specific details as to the aerosol model approach in YYY and data harmonisation methods in ZZZ; examples and tutorials can be found at grasp-earth.com."

**Response:**

The section 2 "SYREMIS/GRASP synergetic concept" is revised and extended considerably with a more detailed description of the synergetic measurements preparation, forward models, instrument "weighting" approach, and a priori constraints in the GRASP algorithm used for the SYREMIS approach.

- Further to that point, it would be useful to know a little more about how the decision-making process behind section 2.2 beyond "A number of extensive case studies were performed to identify the most optimal retrieval setup." I expect that this was trial-and-error (which is fine) but it'd be useful to know what you were looking for in order to understand how these weights should be interpreted in future. What were you trying to optimize (e.g. best correlation with AERONET, smallest residuals, spatially coherent fields, minimal processing time, results that 'looked right', eliciting minimal complaints from ESA technical officers)? Why did you pick the values of weight you did (i.e. are they similar to the expected uncertainty or were they convenient round numbers)?

**Response:**

The new section 2.4 "Remote sensing tests to optimize synergetic retrieval" is introduced. It contains all information regarding tests performed to validate and optimize the synergetic approach. The section describes which validation datasets were used for these purposes and what the criteria were to select the best approach.

- In lines 213-214, the terms "weighting" and "standard deviation" appear to be used as synonyms. On line 201, they appear to mean different things (SD being the variation of data going into the harmonization and W being the value given to the retrieval code to use within a covariance matrix). Please check this section to make sure you are being consistent.

**Response:**

Updated Sections 2.2, 2.3, and added Appendix A describes the "weighting" due to measurements and a "weighting" due to a priori datasets (smoothness constraints) in the GRASP algorithm and how they were used in SYREMIS synergy (section 2.2 - 2.4, Appendix A).

- The wording of lines 254-259 has confused me. You say that the combination of three instruments "contains more information about temporal variability", but I thought that the opposite was the case? As more instruments are added to each harmonized "pixel", that pixel represents a greater window of time and so contains *less* information about temporal variability because it is smoothing over a longer duration. Thus, the smoothness constraint becomes smaller because the expected covariance of subsequent pixels has decreased. I could be entirely wrong here, as I think in covariances rather than in smoothness constraints which may be misleading me.

**Response:**

Speaking about “more information about temporal variability” from the combination of the instrument, we mean the information from the synergetic measurements themselves. For example, for any colocated pixel from 3 different LEO+LEO satellites, there may be a few measurements at different times within one day: S3A/OLCI, S3B/OLCI, and S5P/TROPOMI. Therefore, the synergetic measurements provide much better information about the temporal variability of aerosol and surface properties than the single instruments. These multi-temporal synergetic measurements are input for SYREMIS/GRASP. With properly adjusted temporal thresholds and “multi-temporal” smoothness constraints (Sections 2.3 and 2.4) this results in the consistent retrieval of temporal dependences of the aerosol and surface characteristics. To describe this in more detail, we updated the description of the synergetic data preparation, introduced the concept of the spatial-temporal dataset block, and provided more details on how these not colocated in time measurements are treated in GRASP with temporal thresholds and a priori temporal smoothness constraints (Section 2).

- It is nice to see a validation of BRDF in section 3.3 as this is commonly overlooked despite most aerosol retrievals considering it to some extent. However, the discussion is rather unsatisfying as Figs. 17-19 exhibit fairly substantial differences between GRASP and MODIS without commentary. I disagree with line 398 that the retrievals are “very similar”. They’re qualitatively similar, but GRASP is much less spatially complete and exhibits differences to MODIS of sufficient magnitude to be relevant and that correlate with surface types. As BRDF is not the focus of this team, I’m not asking for a robust validation but, at a minimum, Fig. 19 deserves more discussion. GRASP is producing a much wider range of values and a qualitative comment upon whether the authors believe their BRDF is better or worse than MODIS would be interesting, if only to inform data users as to whether the team thinks there is any scientific merit in the product.
    - Also, on lines 405 and 456, you state that the MODIS BRDF is a one-angle observation. When one refers to “MODIS BRDF”, I think of MCD43A1, which is based on observations from a 16-day window in order to capture a range of angles. There is surface reflectance in the MOD04/MYD04, but that isn’t presented in terms of the Ross-Li kernels. The authors should specify which product they are comparing against and, if it is MCD43, describe it appropriately.
    - There is no acknowledgement for the MODIS data used. I believe all of the datasets now have a DOI.

**Response:**
For the global intercomparison with the SYREMIS Ross-Li BRDF model parameters, the MCD43C1 dataset was used. This is explained in Sec.3.3, with reference DOI provided. Indeed, the MCD43C1 daily BRDF product was produced using 16 days of Terra and Aqua MODIS data covering a range of scattering angles.
In the BRDF intercomparison maps, SYREMIS and MODIS BRDF maps differ in spatial completeness over the Amazon and high-latitude regions mainly due to differences in cloud/snow masks for TROPOMI/OLCI and MODIS. Aggressive cloud/snow masking was employed for TROPOMI; this may remove more pixels compared to MODIS, especially in regions such as Amazon, high-latitude regions,

and Tibet. In the revised manuscript, we provided more discussion in Section 3.4 about the differences in the global distribution of AOD and BRDF.

Overall, the stronger variability of the second and third BRDF parameters from SYREMIS can be explained by the pseudo multi-angular measurements in the synergetic retrieval with much more angular information (up to 150 accumulated measurements in LEO+LEO synergy within 1 month) than from any of the single instruments with one observation angle per measurement (MODIS, S5P/TROPOMI, S3A/OLCI or S3B/OLCI, etc.), even though the 16-day aggregated retrieval method was used for the MCD43C1 product. Due to this fact, SYREMIS synergy measurements provide more information about the surface angular reflectance properties, which, we think, results in better characterization of BRDF parameters representing surface angular dependence.
A separate manuscript, currently in preparation, will present a global intercomparison between SYREMIS and reference satellite surface products, including MODIS and VIIRS, with an in-depth analysis of their differences.

- At line 433, my gut instinct is that TROPOMI provides the most information, rather than the richest information, as a greater number of channels are utilised. To comment on the richness of the information would require considering, say, the number of degrees of freedom per input channel. (This may very well be highest for TROPOMI as it has good uncertainty characteristics, but that isn't examined in this manuscript.)

**Response:**
TROPOMI provides more information due to both a wider range of spectral measurements (from UV to SWIR) and a much wider swath than OLCI, for example. In the paper, we used "richest information" as a synonym for "the most information". Indeed, to avoid confusion with information content analysis, we will use the phrase "the most information" in the revised manuscript.

The paper's weakest area is its language, which was difficult for this native speaker to read. It is technically correct but uses an unusual syntax that took some getting used to. A number of corrections are offered in the attached PDF but there are two recurring issues that warrant mention here.

- I am unfamiliar with the use of "essentially" in this paper. It appears to be used where "significantly" or (better) "substantially" would be.
- "The" is frequently used incorrectly. I admit that the rules for "the" are difficult to explain, but it usually refers to something singular or unique: the GRASP algorithm is different to an aerosol retrieval while the MODIS dataset is different to a datapoint. A copy-editor would be exceedingly useful in this regard as I didn't catch them all.

**Response:**
We are very grateful to the reviewer for the corrections he kindly made in the paper. All of them were accounted for, and the English language was improved.

**Note in the updated validation plot above, the number of datapoints N in each plot is different compared to the number of datapoints in the original Figs. 2 and 3 in the first submission of the manuscript; this is because the updated plots were created with updated AERONET Level 2 products. The latest access date to AERONET is 2025 July**

**18, which is about 2 years after the creation of the original plots in the first version of the manuscript.** “