Response to Stefan Kinne

We thank Stefan Kinne for giving a positive feedback on the revised (based on his comments) version of the manuscript which was published in AMTD

Extended validation and evaluation of the OLCI-SLSTR synergy aerosol product (SY_2_AOD) on Sentinel-3 *by L. Sogacheva et al.*

1 Highlights

- *now inclusion of fine-mode AOD analysis*
- *now much better plots on behavior for different AOD regions*

2 Concerns

- *discussions are too brief (also provide use-recommendations to potential users?)*
  Discussion has been extended.
  Our aim was to perform a critical and detailed evaluation of the Sy_2 product which shows where an improvement of the product is required. Based on this analysis and users needs, they can decide if the product satisfies requirements for their study or not.

- *missing comparisons to the standard SLSTR retrieval (to justify the synergy approach)*
  we reply to this comment below (Specific comments, 119)
- *no fine-mode AOD results in the abstract and fine-mode AOD comparisons to MODIS*
  Results are added
- too extensive comparisons to AERONET
  we aimed to show the performance of the product in different spatial/temporal/geometry conditions and find AERONET is a best choice for that (though we know that AERONET stations are not distributed evenly globally)
- consider AERONET mid-vis AOD <0.04 (and/or remove mountain AERONET site data)
  We answer to this comment below

3 General comments

The paper investigates the performance of a combined OLCI and SLSTR retrievals for AOD, Angstrom (via spectral AOD dependence), AAOD (?), AODf and surface reflection.

The paper investigates the performance of a combined OLCI and SLSTR retrievals for AOD, AOD uncertainty, Angström (via spectral AOD dependence), AODf and FMF. AAOD and surface reflectance are not among validated/evaluated products.

I assume that the SY_2_AOD retrieval performance mainly mirrors for SLSTR covered regions, the SLSTR retrieval performance with a degraded performance in regions, which only the OLCI sensor covers.

AOD in OLCI-only covered areas is not retrieved

Here comparisons and use-statements are at least needed for the discussion section at the end. The discussion section should also address why anyone (user) would want to work with SY_2_AOD in comparison to available data from SLSTR (which still have major issues) and especially over available data from MODIS, VIIRS or MISR.

In the current manuscript we aim for evaluating the SY_2 AOD product. Scatter density plots show the presence of outliers (analysis of the outliers, including identification of the location of outliers, is included in LAW validation report); corresponding validation statistics, binned analysis, fraction of matchups in MODIS EE and fraction of matchups which satisfy GCOS requirements show that improvement of the Sy_2 product is needed. Detailed (regional, dust/single retrieval) analysis allows recognition of the conditions in which product quality is better and where an improvement is needed. Based on the validation results, we do not provide recommendations; users can decide if product quality satisfy the requirements for their study (e.g.,for regional analysis) or not.

I could not find a detailed response to my initial review so some of the concerns I voiced in my initial review are still valid. On the other hand, I very much like in the revised version the new plots that analyze the retrieval performance as function of AOD ranges. These new figures provide much more insights that scatter plots and tables and I suggest to move (the more general performance summaries of) tables (e.g. positive bias but linear fit slope below one seem inconsistent … without the AOD range analysis) and scatter plots - as well as uncertainly analyses into an Appendix or supplement, as the paper is very long and exhausting on the comparisons to AERONET (e.g. I did not know that spectral surface solar reflection is an official AERONET product).

Some figures and tables were moved in the supplement. Scatter density plots are left in the main paper, since they show important information, e.g., a distribution of outliers. We also consider that results from the evaluation of provided uncertainties is important for modellers, who exploit AOD uncertainties in models.

In that context, I also would focus on AERONET data with mid-vis AOD > 0.04 (as lower values are likely related to mountain sites, which should not be considered when comparing to regional data (even for regions as small as 3.5x3.5km areas).

As suggested, we tested removal of the matchups with aAOD<0.04 from the analysis, but the main results (global, for the NH and SH) have not changed considerably. Thus, we keep old results (for all matchups) in the manuscript.

Many important regions for aerosol properties have no or only poor AERONET coverage, so comparisons to global data-sets are essential for a complete pictures. Thus, the effort to compare at the end to a commonly used and likely more mature data-set of MODIS (although potentially with biases, as MODIS AOD overestimates over oceans) is well received, but offered comparisons are way too brief and also miss potentially important AODf comparison (AODf over oceans is offered by the standard MODIS 6.1 product and over land AODf data are available by MODIS-DB AODdust [AODf ~AOD-AODdust] by Pu, B., Ginoux, P., et al., Atmos. Chem. Phys., 20, 55–81, 2020).

We suppose that regions chosen for validation cover most common surface/aerosol conditions globally.

As suggested, we extended FMAOD and FMF evaluation with AERONET.

We also added syFMF and mFMF inter-comparison for test case (26.02.2020).

Validation with ground-based measurements provided valuable information about the product. Extended evaluation with satellite products will be performed when Sy_2 validation results will show a better performance of the retrieval algorithm.

The discussion summary is very brief and disappoints on content, more so since in the data-comparisons, the focus was just on differences and performance with no (or at best little) efforts on interpretations. I strongly suggest to expand the discussion section on major results and their background, so that a reader has a more satisfying element from this comparison paper.

The discussion section on major results was expanded. We added interpretations of the results, where reasons for insufficient quality are clear. However, for some results, interpretation is not possible without painstaking testing of the algorithm performance, which is planned to be done based on the validation results. As suggested by another reviewer, subjective conclusions like "good agreement" were accompanied with quantified results.

4 Specific comments

27 *is there a way to get rid of large outliers (e.g. with a better QA control?)*

AOD quality flags are not provided in the SY_2 product

30 *the abstract does not address high AODf bias (for coarse mode dominated references)*

Results are added

119 *the aim "to allow for a more robust retrieval" needs to be demonstrated (e.g. vs SLSTR)*

Validation results for the SLSTR v1.12 are not published as a paper yet but available on the CCI web-page. We provide a link to those results but do not perform an inter-comparison of the SLSTR and SY_2 validation results in the current manuscript for several reasons:

- we aimed at extended validation with high quality ground-based measurements to evaluate the performance of the algorithm in different conditions. We consider that the results presented describe well the status of the product and allow recognition of the "weak" parts in the retrieval algorithm, which helps in the further development of the retrieval algorithm.
- inter-comparison with the SLSTR, if done properly, requires considerable effort (e.g. pixel-to-pixel, retrieved in both products, inter-comparison; repeating SLSTR validation for the same period when Sy_2 product is available, ets.) which was not covered by the tasks in the LAW project
- We agree that an inter-comparison may add additional information. However, the inter-comparison results should be accomplished with a set of figures and discussion, which will extend considerably the current manuscript, which is already long. Detailed inter-comparison with other satellite products may be a subject for another study/manuscript.

Indeed, some validation statistics for the current version of Sy_2 product (retrieval approach follows the main principles and, with some delay, modifications in the SLSTR retrieval algorithm) are slightly worse compared with SLSTR v1.12 product. However, Sy_2 product is a new product, which is still under development. The validation results reported in the manuscript may also help in further development of the SLSTR AOD product, since the main retrieval approach is simitar for both products.

119 *The aim "to offer data over the entire Sentinel-3 swath" should also be addressed in the discussion (vs SLSTR). I assume similar quality in OCLI only regions over oceans, but significantly reduced quality over OCLI only regions over land.*

Over land the retrieval is performed when both SLSTR and OLCI are available

130 *As different products are offered (e.g. all, dual, nadirS, NadirO) are there reasons why particular versions show be used or avoided in particular regions? If the performance all these different SY versions are addressed, there should be some discussion on their use at the end.*

One product – Sy_2 AOD – is offered. In this product, AOD is retrieved with two different processors, dual or single, depending on the L1b data availability in nadir and oblique views. Based on flags provided, a user can choose which results (if not all) to use. To help users, we provide validation results for different groups of pixels, combined base on the retrieval approach applied.

177 *the Angstrom parameter of the retrieval with AOD at 550 and 865nm over land could be highly inaccurate over vegetation (large/uncertain surf near-IR contributions … any comment?)*

We agree that contribution from the vegetation may be a source for AE errors

295 *aAOD as low as 0.02 permitted? (I would use aAOD>0.04 – as a simple way to exlude mountain sites … although a mountain site exclusion to begin with would be better). I suggest to used aAOD >0.04 only.*

We answered to this comment in the section "General comments"

298 *these biases at low AOD are shocking! Why would anyone want to use that product?*

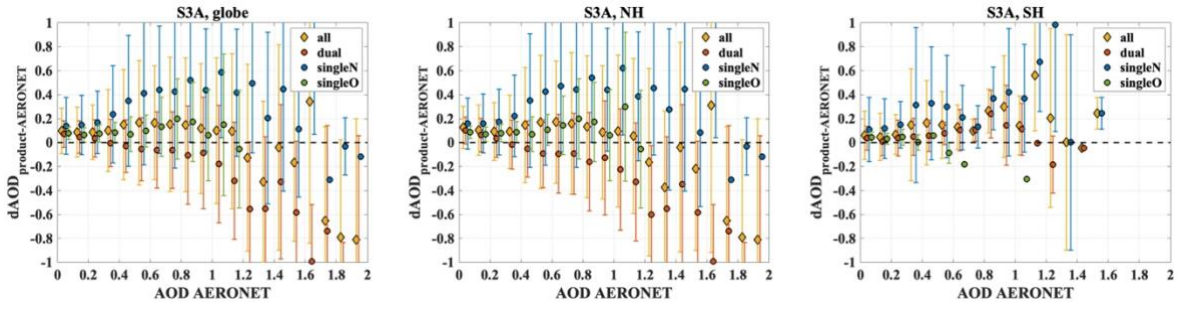
Our aim was to evaluate the first version of the product and show conditions in which a further development of the retrieval algorithm is needed. Users can decide if the quality of the product is enough for their studies (e.g., if they are interested in regional analysis) or not.

305/315 420/424 528/544 654/660 *scatter plots and tables (and the explanation) in the Appendix as Figures 3/7/13/19 better tell the entire story.*

We agree that Figures 3/7/13/19 better tell the story, but not the entire story. Scatter density plots shows clearly, e.g., the distribution of outliers. This information is hidden in the binned plots (e.g., in Fig.3) .

We moved Tables 2-5 into the supplement.

We also added a new figure, where binned offsets (shown also in Fig.2 as magenta dots) for different groups of products (all, dual, singleN, singleO) are combined into one plot (see below). This kind of visualisation shows clearer offsets to AERONET for pixels retrieved with different approaches and the difference in the results for the NH and SH.



385 *SH Jul-Oct correlation is much better, since (biomass related dry-season) AOD values are higher … so no surprise here.*

Correlation is also good for AOb and Aus, where only low AOD matchups are available

503 *how are uncertainties considered (via weights …?). It is not possible just to remove all data below a specific uncertainty threshold for a higher quality product?*

Uncertainties are considered via weights. AOD quality estimate is not provided in the product. In general, uncertainties can be considered as a quality measure, but provided uncertainties for low AOD are often overestimated.

520 *what is the value of comparing AOD at longer (865 and 1600nm) wavelengths, when aerosol signals are much weaker (or are completely missed when fine-mode aerosol dominates)?*

Often, AE is calculated using AOD_{865}. The knowledge on the AOD_{865} quality is important for explanation of the AE quality.

800 *apparent land-sea contrast in SY data (also easily seen in differences to MODIS) need some explanations. I also strongly encourage to extend such comparisons to the AODf for more insights.*

We included an inter-comparison between syFMF and modFMF (provided in the MOD04_L2 product) for test case described in Sect.8.2 as Fig. 27 in the revised version of the manuscript. Unfortunately, MODIS FMF coverage over land is poor, and thus it can be used for clarification of the difference between syAOD and modAOD.

870 *remove "SKYNET, SURFRAD"*

We decided to mention SKYNET and SURFRAD here. It is mentioned in the paper (in Introduction) that validation was performed also with SKYNET and SURFRAD and that validation results are provided in the supplement.

878 *the discussion (e.g. "Against MODIS, agreement is good") is way too superficial. MODIS overestimates AOD over oceans (compared to MISR, AATSR and AVHRR-DB … and modeling) so that the relative high SY AOD values over oceans, although they compare to MODIS there) are not really encouraging. A closer inspection will also show that SY AOD – also over oceans – are much more fine-mode dominated than most another satellite retrievals (and modeling), which in part causes the land/ocean contrast of Africa for larger dust outflow AOD.*

Validation with MAN shows no bias in SY_ AOD. We add numbers showing the difference between product instead of saying that "agreement is good"