Response to anonymous reviewer #2

Thank you very much for your positive review and your helpful comments – they have improved the manuscript greatly.

Review of "Extended validation and evaluation of the OLCI-SLSTR Synergy aerosol product (SY_2_AOD) on Sentinel-3" by Sogacheva et al.

Summary:

This paper presents the synergy AOD product from Sentinel-3 and its evaluation against a set of other global AOD products. This is obviously product of a thorough comparison, from the use of validations against AERONET, MAN (and SURFRAD and SKYNET in supplement), and MODIS datasets, and the breadth and level of detail of the manuscript shows it. This is a high-quality manuscript and should be published in AMT, and will likely be used as reference for many other validation of satellite aerosol products. While this manuscript is long, it is obviously needed, and the quality of the work is appreciated.

I recommend this paper to be published, but after addressing these issues:

- *The linear fitting scheme is not well identified, or may not be appropriate for AOD fitting, and by the manuscript's own analysis (section 6.1.5), this matters for quantifying the overall fit. See the general comment #6. This would not be brought up as major concern except for the fact that it is highlighted in the manuscript already.*

Clarification is added to the text that Pearson correlation coefficient was calculated; linear fitting was performed using polynomial. To shorten the manuscript, as requested by the reviewers, we moved results from Sect. 6.1.5 into the Supplement. Link to the Matlab tool for linear fitting considering uncertainties is provided

- *There are numerous errors in formatting throughout the manuscript which detracts from the quality.*

We checked thoroughly AMT requirements for formats and corrected formats accordingly

- *The description of the retrieval methodology is unclear. How does the retrieval of AOD at multiple wavelength and single scattering albedo is achieved through fitting of AOD at only wavelength (550 nm)?*

This is now clarified (line155): We fit both AOD and FMF, which controls the spectral variation of AOD. All wavelengths of SLSTR, and additionally the 442.5nm OLCI channel over land are used in this fitting.

General Comments:

1. *Several language issues are found within the abstract, and there is need for more quantitative indication in the abstract instead of the subjective descriptions (see specific comments below)*
   We revised the abstract and provided quantitative indication for the results reported
2. *Throughout the document the date format does not seem to meet the AMT standard of "Date and time: 25 July 2007 (dd month yyyy), 15:17:02 (hh:mm:ss)", particularly evident in the paragraph at line 79-89. See the guidelines: https://www.atmospheric-measurementhttps://www.atmospheric-measurement-techniques.net/submission.html - mathtechniques.net/submission.html#math*
   Date format is corrected in the manuscript according to the AMT standard
3. *How much time is passed between measurements in the oblique and nadir view? And how does that impact the aerosol retrieval, particularly near clouds?*
   To our knowledge, an offset between oblique and nadir view measurements is 1-2 minutes. Cloud screening is performed for both views; cloud edge test is applied
4. *The retrieval dictates the retrieval of AOD and its fine mode at 550 nm, however returns many more parameters, including single scattering albedo, at various wavelengths. This is poorly described, and is*

both referred to as 'aerosol properties retrieved' and 'intended as diagnostics' (section 2.2.2). Please clarify what these properties are, and how they are retrieved, especially when only fitting to AOD and fine mode AOD at 550 nm.

This comment is addressed in Sect. 2.2.2

5. *Many references and citations are only links to websites, many of which should be replaced by the appropriate citation, and many are missing the date accessed.*

   Most of the links are for technical specifications of the instruments; these links are suggested by ESA as a reference. We checked citations and changed links to the appropriate citations, where possible. However, since S3 is a relatively new mission, not many results are published in the journals. Thus, we refer to the mission documents and results obtained from other projects which are not published yet. If missing, the dates of acceptance are added.

6. *The type of linear regression is not identified, and this matters for AOD comparisons. Reference to a 'linear regression' between the aAOD and syAOD is presented, however it seems to imply the use of the Ordinary-Least-Squares (OLS) commonly-used fitting routine. This is unlikely to be suitable for this data as the 'independent' variable (aAOD) is subject to uncertainties, and AOD typically do not have gaussian error profiles, which are needed for the OLS. Other fitting routines are recommended to be used, like the 'Yorkfit' (York et al., 2004) or a bivariate regression (e.g., Shinozuka et al., 2015). Similarly, some considerations to the "R" parameter should be mentioned – is it the common Pearson linear correlation coefficient or the*

   Spearman's rank correlation as suggested for use in Sayer et al., 2018. It seems uncertain what is used in Matlab's linear model, or how uncertainty is weighted.

   Clarifications for correlation coefficient and linear regression type are added. We agree that linear regression applied to the full range of AOD does describe details and results may be strongly influences by the outliers. Thus, we included in the revised version binned AOD analysis, which shows AOD offset at different AOD ranges.

7. *There seems to be a significant reduction in error statistics when using the Single Oblique angle, than the single nadir view and even the dual views, however this is not mentioned much, and leads the reader to question the validity of the nadir viewing measurements as a result. (see table 1)*

   Pixels retrieved with single processor applied to the oblique view are ocean pixels. Retrieved AOD over ocean is, in general, of better quality, because ocean surface reflectance model provides better results that land reflectance approach.

8. *There seems to be lower discrepancy between syAOD and aAOD in regions of significant biomass burning aerosol (higher AOD Bor, NAW, AOb for example). This raises the question on what type of single scattering albedo is used, and how does the selection of this model impact the AOD retrievals.*

   This is now clarified (line 157): The SSA is constrained by climatology for the coarse and fine mode extremes separately and as a priori information. The retrieval of FMF results in a SSA by interpolation between these extremes; however, this should be seen as a potential diagnostic for retrieval performance rather than a user product.

9. *Throughout the conclusions section there is a significant amount of qualitative wording such as 'agreement is good' This is subjective and not always supported by the comparisons presented in this manuscript. Either give comparison values to what it is expected to be, or refrain from these subjective statements.*

   Statements like 'agreement is good' are accomplished now with values or removed

10. *There is no mention of potential impact of varying single scattering albedo on the AOD retrieval in the conclusion. Is this a solved issue?*

    This is included in the conclusion now.

Specific Comments:

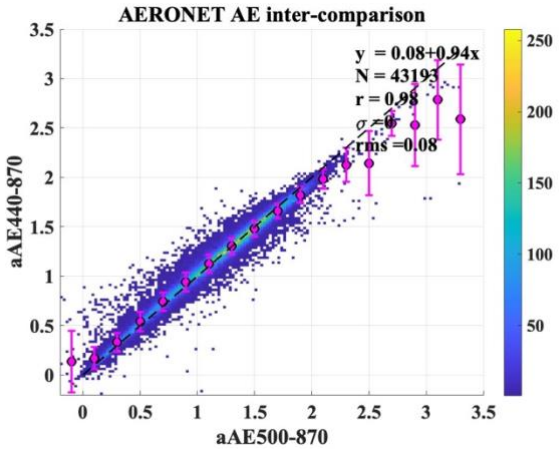
11. *Title: 'Extended' seems to be slightly overexaggerating for a year and half in terms of satellite data comparisons. Suggest to remove that word from the title.*

    We use "extended" not regarding the length of the product, but different validation approaches (including spatial and temporal variations and investigation of the validation results with respect to satellite and

solar geometries) and number of variables which are validated and evaluated (AOD, AODunc, FMAOD, FMF, AE)

12. *Line 14: The word 'synergy/synergistic' is used twice in the first sentence.*
    In the first sentence we explain the origin of the name of the product: the name "synergy" comes from the "synergetic" approach. Thus, the word 'synergy/synergistic' is used twice
13. *Line 24: The use of double +/- is confusing, is this the error of the error based on AOD, or the potential range of the error?*
    The error depends on AOD: for higher AOD, the error envelope is wider
14. *Line 29: Use of "Angström" should be consistent throughout the manuscript, the "ö" is missing on this line.*
    Corrected in the whole manuscript
15. *Line 30: AE is not defined.*
    AE is now defined in the previous line
16. *Line 28-35: use of subjective descriptions should be made more quantitative e.g., "good correlation", "agreement is better", "often slightly better". By how much, how often, and compared to what?*
    Quantitative description (when possible) is added
17. *Abstract: the extent of the evaluation is not introduced. How many days, years, or number of comparison points are used here?*
    Validation period is added to the abstract. Since number of the matchups differs from one exercise to another, depending on the tasks, further datails (e.g., number of validation points) are reported in the main text
18. *Line 108, and throughout the manuscript: there should be a space between the number and the unit '500m'*
    Corrected
19. *Line 102 and 105, please reference the proper citations for SENTINEL-3 OLCI and SLSTR instead of the websites.*
    We used citations recommended by ESA
20. *Line 102 and subsequent, is it capital case SENTINEL-3, Sentinel-3, Sentinel 3? Please select one and use is consistently throughout the manuscript.*
    Checked and corrected in the whole manuscript
21. *Line 113, is there a better reference than this website document for the aerosol retrieval? Seems like this is an important publication for better understanding the material presented in this manuscript. Particularly to support the statement "is of variable quality, with higher uncertainty in retreievals in the oblique backscattering direction." (which has a typo at line 114).*
    The manuscript which describes the retrieval is under preparation. Typo is corrected
22. *Does the shift vectors (section 2.2.1) also have a rotational portion, or is it only translational shifts?*
    Small window (grid) moved around the search window (along shift vectors) in OLCI channel geometry (https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-3-synergy/definitions/notations)
23. *Lines 137 and 145 seem to be repeated "at least 50% of valid pixels"*
    The text is re-phrased, repetition is removed.
24. *Line 147, it is unclear what is meant by 'direction'. Is it viewing direction or viewing angle?*
    Viewing direction, clarified in the text
25. *Line 151, Does 442.5 spectral band refer to 442.5 nm ?*
    Yes, clarification is provided
26. *Line 186, What is "Copernicus C3S_Lot2" ?*
    We added clarification for the project title, but could not find a proper link to the project description and project documents
27. *Line 214, why the shift in multiplication symbol from "x" to "*"?*
    "*" is replaced with "x" in the whole manuscript

28. *Figure 2 is too small.*
    The fonts are corrected
29. *Line 297, How big are the bins in Figure 2?*
    Clarification is added to the figure caption
30. *Line 311, GCOS is not defined.*
    GCOS is now defined
31. *Table 1 – decimal point is comma "," instead of point "."*
    Done
32. *Line 342, typo "bind"*
    Corrected
33. *Line 380, sentence is unclear, is syAOD550 different to S3B syAOD$_{550}$?*
    The sentence is re-phrased
34. *Line 446, equation 1 does not seem well formatted*
    Equation 1 is now formatted
35. *Line 448, use of * instead of multiplication symbol (×)*
    Corrected. Space between x and aAOD is added, because xaAOD is confusing
36. *Line 452, Latitude in [-30 -20] is not well defined, are these degrees south? Is the range inclusive?*
    °S is used now instead of '-'
37. *Line 453-457, formatting error? dAODrel or is it dAOD$_{rel}$ or dAOD,rel (in figure 8, 9)*
    In the text, formatting is corrected as it is in figures
38. *Line 453, typo? What is "ca"*
    Replaced with ~
39. *Figure 8, Units on x-axis not identified (Degrees?)*
    Clarification added to the figure caption
40. *Line 547, What is Aerosol_cci+?*
    Link to the project is provided in Sect.2.2
41. *Line 595, these distribution don't look very Gauss-like, they seem clearly skewed, particularly singleN.*
    Agree, but it is expected to be Gauss-like
42. *Line 617, second apostrophe is not the right side.*
    Corrected
43. *Line 672-673, portion of this sentence is in red.*
    Corrected
44. *Figure 22, AOd region is missing a portion of the red dashed curve. (similarly in Figure S10 AsN, and S11 AOb)*
    Red-dushed curve is missing in the bins where fine-dominated matchups are missing (blue dots, which are results for fine-dominated matchups are also missing then). However, during the checks, we noticed that the fraction of fine-dominated matchups was calculated from the sum of fine- and coarse- dominated, which is right for AOD binned analysis, but not for FMAOD and FMF analysis, where back-ground matchups may exist in any bin. This is corrected, fraction of coarse-dominated is added. Dushed lines for fine- and coarse-dominated fractions are now in blue and green, respectively, as colors for corresponding offsets. The reason for missing a dashed line values at certain bins is the same as it was early – missing fine- or coarse-dominated matchups in the corresponding bin.
45. *Line 698, Isn't AERONET reported at 440 -870 nm? What is a personal estimation? AE difference when using a difference in wavelength has been reported in multiple other papers, e.g., LeBlanc et al., 2020, Yoon et al., 2012*
    syAE is reported at 550-870 nm. For evaluation, aAE 500-870 was utilized.



We checked an agreement between $aAE_{440\text{-}870}$ and $aAE_{500\text{-}870}$ (figure above) and assumed the same agreement between $aAE_{500\text{-}870}$ and $aAE_{550\text{-}870}$. An offset between $aAE_{440\text{-}870}$ and $aAE_{500\text{-}870}$ for low (<0.25) AE and high (~2, which is a default value for syAE) AE (which is ~0.2 and ~0.1, respectively) is considerably smaller than an offset between syAE and aAE in those AE size ranges, thus the difference between aAE440-870 and aAE500-870 can be omitted.

46. *Figure 24, There seems to be a common clustering of high syAE, at or just above 2.0. Is this a default limit of AE from the retrieval? Or is this a real behavior of the aerosol?*

    This is a default limit of AE from the retrieval

47. *Line 735, "good quality" is subjective, but an rms of greater than 0.5, and R often lower than 0.5, with biases often exceeding 1.0 does not seem to be of 'good quality'.*

    We made clarification in the text

48. Table 7, the decimal notation is a comma "," not a dot "."

    Corrected

49. *Figure 28, labels of map regions is too small and of bad quality to read.*

    Fonts/labels are corrected

50. *Line 785, second time AOI is defined.*

    Regions for validation with AERONET are defined in Fig.5, Sect.6.3.1. Area of interest for inter-comparison with MODIS is defined in Fig.28 (as in AMTD) and in Table in the Supplement

51. *Supplement 1, there is an "Error! Reference source not found." At the 4th to last line of the first page.*

    The sentence is removed

52. *Supplement section 1 and 2, there seems to be no mention of the singleO – oblique angle viewing in the comparison to SURFRAD and Skynet*

    Low number (or absence) of matchups in group singleO (most pixels in this group are ocean/coastal pixels) did not allow to perform validation with SURFRAD and SKYNET

References:

LeBlanc, S. E., Redemann, J., Flynn, C., Pistone, K., Kacenelenbogen, M., Segal-rosenheimer, M., Shinozuka, Y., Dunagan, S., Dahlgren, R. P., Meyer, K., Podolske, J., Howell, S. G., Freitag, S., Smallgriswold, J., Holben, B., Diamond, M., Wood, R., Formenti, P., Piketh, S., Maggs-Kölling, G., Gerber, M. and Namwoonde, A.: Above-cloud aerosol optical depth from airborne observations in the southeast Atlantic, Atmos. Chem. Phys., 20, 1565–1590, doi:10.5194/acp-20-1565-2020, 2020.

Sayer, A. M., Hsu, N. C., Lee, J., Kim, W. V., Burton, S., Fenn, M. A., Ferrare, R. A., Kacenelenbogen, M., LeBlanc, S., Pistone, K., Redemann, J., Segal-Rozenhaimer, M., Shinozuka, Y., and Tsay, S.-C.: Two decades observing smoke above clouds in the south-eastern Atlantic Ocean: Deep Blue algorithm updates and validation with ORACLES field campaign data, Atmos. Meas. Tech., 12, 3595–3627, https://doi.org/10.5194/amt-12-3595-2019, 2019.

Shinozuka, Y., Clarke, A. D., Nenes, A., Jefferson, A., Wood, R., McNaughton, C. S., Ström, J., Tunved, P., Redemann, J., Thornhill, K. L., Moore, R. H., Lathem, T. L., Lin, J. J., and Yoon, Y. J.: The relationship between

cloud condensation nuclei (CCN) concentration and light extinction of dried particles: indications of underlying aerosol processes and implications for satellite-based CCN estimates, Atmos. Chem. Phys., 15, 7585–7604, https://doi.org/10.5194/acp-15-7585-2015, 2015.

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