Review of manuscript amt-2019-96: The role of aerosol layer height in quantifying aerosol absorption from ultraviolet satellite observations by Jiyunting Sun et al.

Summary

This manuscript documents a statistics-based approach referred to as SVR (support vector regression) to retrieve single scattering albedo using MODIS retrieved aerosol optical depth (AOD) and TROPOMI UV Aerosol Index (UVAI) and aerosol layer height (ALH) from TROPOMI radiance measurements in the Oxygen-A band.

AERONET ground-based aerosol observations and the 13-year satellite OMI aerosol record (OMAERUV product) are used to build a training data set. The OMAERUV component of the training data set consists of a sub-set of ancillary parameters as well as UVAI and ALH values assumed in OMAERUV for the simultaneous retrieval of AOD and SSA. The resulting training data set includes only UVAI and ALH values associated with high accuracy OMAERUV AOD/SSA retrievals as measured by the difference between collocated AERONET and OMAERUV reported parameters (not larger than 0.03 for SSA and better than 5% for AOD).

Two versions of the trained SVR algorithm were used to retrieve the SSA of an aerosol plume over the Pacific Ocean off the coast of Southern California on December 12, 2017. Retrievals were also carried out using a conventional radiative-transfer-based algorithm, referred to as RTM by the authors. Comparison of the three satellite-based retrievals to AERONET Version 2 retrieved SSA at 500 nm (University of California Santa Barbara site) shows that the three space-based inversions agree with the only AERONET ground-based measurement available within AERONET's stated uncertainty (±0.03). On the other hand, the spread of the three satellite based SSA retrievals over the AERONET site is 0.01.

The authors examined the resulting SSA spatial variability over the extent of the plume, and conclude that the results of the SVR retrievals that show higher homogeneity are more convincing than the RTM approach that shows more spatial variability.

Comments

The authors have not demonstrated that the proposed SVR algorithm performs better than conventional RTM-based approaches. Deriving conclusions on the suitability of a retrieval method based on just one independent measurement is scientifically dubious. The author's accompanying argument that the lower spatial variability of the SVR approach makes the result more convincing is purely subjective and lacks the backing of a rigorous error analysis. It also ignores the radiative and dynamic interaction between the aerosol plume and the atmosphere that could generate SSA heterogeneity over a plume stretching over hundreds of kilometers.

The authors should carefully build an evaluation dataset using as many AERONET observations as possible, to judiciously examine the SVR algorithm performance. The interpretation of spatial variability is certainly not easy. Perhaps, CTM-generated data could also be used for this purpose.

I see a problem with the use of the AERONET as both training and evaluation tool. Unlike the AOD, AERONET SSA is not regarded a 'ground truth' measurement. The SSA is the result of an inversion procedure that yields non-unique solutions, and can produce different answers as the inversion algorithm evolves. For instance, for the case study in this paper the AERONET V2 500 nm SSA value used for evaluation of the satellite retrieval was 0.960. In the recently released AERONET V3 data, the reported SSA for the same event is now 0.982. If a SVR operational algorithm is in place, does the algorithm needs to be re-trained every time a new version of the AERONET data becomes available?

Based on the above consideration I do not think this work is publishable in its current form. Additional specific comments follow.

Specific comments

Line 29: Equation (1) is not consistent with equation given in Herman et al [1997]. What is the meaning of λ and λ_0?

Line 31: Such a SSA global long-term record derived from the information content of the UVAI already exists [Torres et al., 2007]. It is produced by inverting OMI observations at 354 and 388 nm (same wavelengths used in the UVAI definition) to simultaneously retrieve aerosol optical depth (AOD) and single scattering albedo (SSA) at 388 nm. The AOD/SSA retrieval approach by the OMAERUV algorithm is fully documented [Torres et al., 2007; Torres et al., 2013] and SSA retrieval results have been systematically evaluated by comparison to the global AERONET SSA record [Torres et al., 2013; Jethva et al, 2014] and to SKYNET [Jethva and Torres, 2019] and MFRSR [Mok et al., 2016] SSA retrievals. The author's disregard of the 15-year near UV SSA record in the literature review is rather puzzling.

Line 38: The label 'RTM-based method' is not appropriate. All atmospheric retrievals methods are one way or another based on radiative transfer calculations. The authors are referring to SSA inversions in the UVAI space that infer SSA by 'matching' calculated to observed UVAI. The listed references on this approach are mostly academic exercises, none of which led to algorithm development. While the UVAI parameter contains information on aerosol properties, it is also affected by land surface effects, ocean color, sub-pixel size clouds, gas absorption, etc. Thus, the direct UVAI to SSA conversion techniques is not an optimal way to extract aerosol absorption from the near UV measurements. It is best to use actual radiances.

Line 47: Please mention the recently developed ALH retrieval capability from EPIC oxygen absorption bands to retrieve ALH of dust layers and carbonaceous aerosol layers over both ocean and land surfaces Xu et al., 2017, 2019]

Line 70: The discussion of SSA retrieval for this event should also include OMAERUV SSA results if available.

Line 111: An UVAI threshold of 1.0 also excludes low altitude absorbing aerosol layers, and low AOD elevated layers.

Line 114: Sensitivity of results of the assumed 50 hPA pressure thickness assumption should be discussed.

Line 130: The Herman et al [1997] assumption (spectrally flat As in the near UV) has been shown to be not generally valid. Is there a reason why the authors do not use the OMI-based Kleipool et al [2008, 2010] databases?

Line 131: In the description of the OMAERUV record, the authors list only the UVAI and ALH and omit the fact that both AOD and SSA are reported retrieved parameters. After all, the reason why the ALH is included in the OMAERUV product is that the inversion requires information on ALH. A more candid description of the OMAERUV product should read '….long-term UVAI, AOD and SSA with corresponding ALH….'

Line 142: Discuss the error bars and whiskers on Fig 2, particularly for the SSA. What are the implications of the expected diurnal variability?

Line 144: The time difference between TROPOMI and AERONET observations on December 12, 2017 is about 2.5 hours. Discuss the implication of that time difference in the context of the AERONET results in Fig 2.

Line 145: Both AERONET SSA and TROPOMI are results of inversions in which multiple solutions are possible. Thus, an inversion cannot be validated with another inversion. Use 'compare' instead of 'validate'. Use 'comparison' instead of 'validation' in all instances in the paper where the word 'validation' is used.

Line 146: Use AERONET version 3 data in the construction of the training data set. There are significant differences between version 2 and 3 of the AERONET inversion product.

Line 170. Provide the reasoning to conclude that the southern part of the plume is the most absorbing region. All it can be said, is that the largest UVAI is observed in that region, but AOD, ALH and spectral aerosol absorption exponent affect the magnitude of the resulting UVAI.

Line 187. Assuming constant refractive index for wavelengths longer than 388 nm is not a reasonable assumption. At longer wavelengths, the role of black carbon is more important. Discuss the implication of this assumption on the reported results.

Line 193: The 'existing' MODIS AOD and TROPOMI ALH retrievals involve assumptions on particle size distribution (PSD) and aerosol single scattering albedo. Are the assumed PSD's in the two algorithms consistent? How about the complex refractive indices assumed in the AOD and ALH retrieval? Please list the values of those parameters and discuss the implication of inconsistencies if any.

Line 206: Please describe in more detail the implied statistical analysis of 13 years of data involving the OMAERUV and AERONET data sets. What are the parameters being examined?

Line 208: The 13-year OMAERUV global dataset includes AOD and SSA, a record that the authors claim back on page 31, does not exist.

Line 212: I am totally lost here. The statement *'samples are excluded if the SSA difference between OMI and AERONET are larger than 0.03 or the AOD difference between OMI and AERONET is larger than 5%'* is incomprehensible. What OMI SSA/AOD are the authors talking about? Are these OMAERUV-retrieved values? Up to this point in the manuscript, the authors have not acknowledged the existence of such products. If these are indeed the OMAERUV SSA/AOD, then the authors have created a dataset consisting of the best quality OMAERUV AOD and SSA retrievals (as measured by the level of agreement with AERONET) to train the SVR algorithm. It is suggest that the description OMAERUV-SSA and OMAERUV-AOD be used (instead of the generic OMI-SSA or OMI-AOD) to avoid confusing the reader since there is a second OMI aerosol algorithm (OMAERO).

Line 228: Add Torres et al 2013 reference to the CALIOP ALH climatology.

Line 232: The UVAI height dependence was first documented [Herman at al., 1997; Torres et al., 1998] based on analysis of TOMS data.

Line 235: If spectrally dependent AOD (354 and 388 nm) and ALH are indeed independently know, one should be able to retrieve the SSA at 354 and 388 nm via a direct RTM inversion of the 354 and 388 nm radiances (not the UVAI). This is the simplest RTM approach that would fully characterize the aerosol plume.

Line 241: Fig 7(c) is not mentioned in the discussion. Remove it if not needed. Otherwise, explain, or eliminate, the difference between UVAI OMI and UVAI OMAERUV in the z-axis label of figures 7(b) and 7(c).

Line 245: As described the ALH adjustment sounds arbitrary. It looks to me the authors are just conveniently making up a convenient dataset. Please provide an understandable rationale for the creation of this ALH *dataset.*

Line 250 There is no mention in this work of the Oxygen-A band AOD that is simultaneously retrieved with ALH from TROPOPMI observations. Shouldn't it be better to use the TROPOMI AOD rather than the MODISD AOD? That would eliminate possible implicit inconsistencies in aerosol microphysics.

Line 259: What does 'rule of thumb ratio 70% versus 30%' really mean? This all sounds arbitrary.

Line 290: Figures should be described sequentially. From the description of figures 7(a) and (7b), the authors jump to Figure 5, and then back to Figure 7(c).

Line 301: The MODIS AOD uncertainty needs to be taking into account and propagated in a sensitivity analysis of the SVR application. Over the US west coast, in particular, the AOD is subject to large uncertainty due to surface effects [Jethva et al., 2019].

Line 323: The difference of 0.01 between the two SVR applications has not statistical meaning, as they are both within the stated AERONET uncertainty of ± 0.03 for a single measurement. Any over-interpretation is just splitting hairs.

Line 326: I disagree with this statement. No measurable improvement in performance is apparent from this comparison. The use of the adjusted ALH instead of the original OMAERUV ALH makes no statistically quantifiable difference whatsoever. A more systematic analysis using a large number of independently measured SSA values is required.

Line 328: In section 4.2, the authors try interpreting the lower spatial variability over the entire plume of the SVR retrieved SSA with respect to the SSA spatial variability resulting from the RTM-based approach, as an indication of better SVR accuracy. The north-south extent of the plume over the ocean is about 1000 km whereas the east-west dimension varies from about 200 to 700 km. For an aerosol plume this large, it is not unreasonable to expect spatial variability in SSA. The SSA of carbonaceous aerosols from biomass burning or wild fires is lowest near the source areas in the flaming phase of the fires. As the resulting smoke layer is transported downwind, it interacts with the surrounding air. Aerosol SSA may increase due to water uptake by hydrophilic particles. The resulting SSA homogeneity over the plume may therefore depend on the homogeneity of meteorological fields.

I do not think this study conclusively demonstrates that the described SVR technique yields more accurate retrieval than standard well thought out RTM approaches. Undoubtedly, however, the availability of TROPOMI ALH observations will improve the accuracy of retrieved aerosol absorption.

Line 345-347: The statement '*In cloud-free cases, it is expected that micro-physical properties of smoke particles within the plume should be similar over short time periods as they were originated from the same source and generated under the same conditions..'* is not always correct. The variability over a large smoke plume like the one used in this analysis may be important.

Line 364: The statement that the proposed method based on the correlation between between UVAI, AOD and ALH requires no a priori assumptions on aerosol micro-physics is incorrect. Implicit microphysics assumptions are involved in the use of MODIS AOD as well as TROPOMI ALH. The authors have ignored this fact, and treat the AOD and ALH as 'given true values', ignoring the fact that these parameters come out as the result of RTM-based inversions that assume particle size distribution, and complex refractive index over an extended spectral range. The results of a sensitivity analysis that propagates AOD and ALH retrieval uncertainties into the SVR method should be included in the paper.

Line 365: The statement '*a priori assumptions on aerosol microphysics is considered one of the major error sources in RTM-based method*' is misleading. I should read instead ' wrong *a priori assumptions* ..'

Line 368: '*Convincing.*.' is not an objective characterization. I was not convinced as stated in this review.

Additional References

Xu, X., Wang, J., Wang, Y., Zeng, J., Torres, O., Reid, J. S., Miller, S. D., Martins, J. V., and Remer, L. A.: Detecting layer height of smoke aerosols over vegetated land and water surfaces via oxygen absorption bands: hourly results from EPIC/DSCOVR in deep space, Atmos. Meas. Tech., 12, 3269-3288, https://doi.org/10.5194/amt-12-3269-2019, 2019.

Xu, X., J. Wang, Y. Wang, J. Zeng, O. Torres, Y. Yang, A. Marshak, J. Reid, *and* S. Miller *(*2017*)*, Passive remote sensing of altitude and optical depth of dust plumes using the oxygen A and B bands: First results from EPIC/DSCOVR at Lagrange-1 point, Geophys. Res. Lett., 44, *doi:*10.1002/2017GL073939

Jethva, H., Torres, O., and Yoshida, Y.: Accuracy Assessment of MODIS Land Aerosol Optical Thickness Algorithms using AERONET Measurements, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2019-77, in review, 2019.

Jethva, H. and Torres, O.: A Comparative Evaluation of Aura-OMI and SKYNET Near-UV Single-scattering Albedo Products, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2019-174, in review, 2019.