Review of ACP-2020-39 article '*Defining aerosol layer height for UVAI interpretation using aerosol vertical distributions characterized by MERRA-2'*, by Sun et al.

Summary

The work described in this manuscript proposes the use of the multi-year long MERRA-2 data base on aerosol vertical distribution from model calculations to derive a long-term record of Aerosol Layer Height (ALH) that can be used in the interpretation of the multi-decadal UV Aerosol Index (UVAI) from a series of instruments, from TOMS in 1979 to currently operational OMI, GOME and TROPOMI sensors, to obtain quantitative information on near UV aerosol absorption. Given the lack of observation-based data on ALH over such a long period, the proposed use of MERRA-2 generated data seems a reasonable approach.

The suggested approach implies the need to account for the multiple spectral dependencies of the UVAI on aerosol microphysical and optical properties, aerosol amount and its vertical distribution (ALH), as well as surface effects including land reflectance and ocean color effects.

The authors go over a series of mathematical definitions of ALH and settle on a particular method. In the next step, they carry out a radiative transfer-based analysis of UVAI sensitivity to their adopted ALH definition and use the results of such analysis to evaluate the suitability of existing ALH products.

General Comments

In their theoretical analysis, the authors underestimate the importance of many physical mechanisms that contribute to the observed spectral dependence captured by the measured UVAI. Their analysis disregards the well-known UVAI dependence on factors other than ALH such as the spectral dependence of the near UV imaginary component of aerosol particle refractive index, also expressed as Aerosol Absorption Exponent (AAE), and the spectral dependence of surface albedo which over arid and semi-arid regions of the world and over the oceans(pure water, chlorophyll and CDOM absorption) contribute significantly to the UVAI signal.

These effects are clearly non-negligible. For instance, at a particular viewing geometry, a 340-380 defined UVAI value of 2.0 for an aerosol layer of AOD (550 nm) 0.5, can be explained by multiple combination of ALH values between about 3 km and 6 km and AAE values between 1 and about 3. Thus, to properly derive ALH information, AAE must be accurately constrained. AAE vary significantly between aerosol types, and even for a given aerosol type the AAE varies regionally depending on soil composition for dust particles, and on fuel composition for carbonaceous particles.

The simplified radiative transfer calculations used in this analysis are based on unrealistic representation of the aerosol scattering phase function. The assumed Henvy-Grennstein (H-G) phase function used in this work does not allow the accurate modeling of the role particle size distribution, particle shape, and complex refractive index. These properties vary significantly for different aerosol types. Accurate radiative transfer calculations using Mie Theory for spherical particles and T-matrix and Geometric Optics combinations for non-spherical particles, must be used to reliably interpret the information content of satellite near UV observations. The aerosol model used in the analysis based on simplified assumptions on asymmetry factor and single scattering albedo is a very crude representation unsuitable for the analysis of satellite data.

For the above stated reasons, this manuscript is not publishable it its current form. A realistic representation of the relevant aerosol types as well as accurate radiative transfer calculations are required to successfully extract the ALH information contained in the UVAI.

Specific comments:

Line 32. The term ‘small’ is ambiguous. Refer to agree-upon size ranges in aerosol definition.

Line 45. Define columnar ALH.

Line 58. Since POLDER does not have any near UV channels, this is a rather strange statement.

Line 64. Clarify that EPIC does not involve spectrally resolved measurements.

Line 67. This is not a peer-reviewed work.

Line 71. The beginning of the paragraph refers to active measurements, but the following discussion abruptly changes to passive measurements. Thus, the whole paragraph looks incongruent.

Line 85. Altitude dependence is just one of the several dependencies of UVAI: spectral surface albedo and aerosol absorption exponent are very important. Discuss those effects and their importance in UVAI interpretation.

Line 114. The statement is not clear. Agreement of what with what.

Line 127. The validation shown in Appendix B uses CALIOP 532 nm extinction profiles. For smoke aerosols, 532 nm profiles are often truncated, and the derived aerosol height is overestimated [Torres et al., 2013] as a result of signal attenuation due to black carbon absorption (Kim et al., JGR, 118, 2013; Kacenelenbogen et al., JGR, 119, 2014; Liu et al., ACP, 15, 2015; Torres et al., AMT, 2013). Should use instead the 1064 nm channel.

Line 152. Aerosol effective geometric height makes more sense.

Line 255. The OMAERUV ALH climatology cannot be considered a single source ALH data base. This product is mainly based on a CALIOP climatology, but also includes model-based assumptions and spatial extrapolations developed to constrain the AOD/SSA retrieval. The authors should not use this data base. They should instead evaluate the CALIOP product on its own merits.

Line 283. Scattering effects of HG idealized aerosols differ significantly from real aerosols. HG aerosols is a 1950’s tool when computing tools were inadequate and, no actual satellite observations were available.

Line 292. What is the point of using non-accessible data?

Line 296. Reference wavelength? How much aerosol is then rejected? At 550 nm only a small fraction of AOD is larger than 0.5. How much data is available after AOD lower than 0.5 is rejected?

Line 314. Same comment as above. HG aerosol type does not exist in the real world.

Line 321. This statement is not correct. CALIOP measures the actual aerosol vertical distribution.

Line 324. Need to explain better the diagnostic role of AOD. AOD must be accurately known to retrieve realistic ALH. How accurate is the retrieved AOD, and how this accuracy translates in accuracy of retrieved ALH? It can be evaluated by comparison to ground-based observations or to MODIS-MiSR products.

Line 326-27. Not the same as O2-O2. It was stated above that AOD < 0.5 are discarded

Line 344. Please provide a peer-reviewed reference.

Line 349. Provide a validation reference like a comparison to CALIOP.

Line 351. This is another non-accessible data set.

Line 358. Retrieval capability over deserts is important. Please include a comparison to CALIOP over the Saharan Desert.

Line 380. Again HG. This sensitivity analysis must be carried out with actual radiative transfer calculations using Mie Theory for spherical particles and the adequate approach for non-spherical particles.

Line 383.How about in the UV? Spectrally invariant SSA in the UV s not realistic.

Line 389. The spectral dependence of surface albedo is important because it generates a ‘spurious’ aerosol signal. It may not be that important in single channel retrievals, but it is quite important for UVAI analyses. The high background UVAI (about 1.0) over arid regions is the result of surface albedo wavelength dependence in the near UV.

Line 393. The current UVAI definition in OMAERUV is not consistent with Equation 5. The new definition accounts for water cloud effects and surface spectral dependence. For historical reasons, the traditional definition (Equation 5) is also reported in the OMAERUV product under a different variable name. Authors should make sure they are using the correct parameter.