Review comments on 'Analysis of the MODIS Above-Cloud Aerosol Retrieval Algorithm Using MCARS' by Wind et al.

This manuscript uses Multi-sensor Cloud and Aerosol Retrieval Simulator (MCARS) and GEOS5 Nature Run (G5NR) model output to simulate the MODIS radiance, run above cloud aerosol retrieval using generated radiance, and evaluate the MODIS above cloud aerosol retrieval product (MOD06ACAERO), focusing on the absorbing aerosol above low-level water cloud scene from Southeast Atlantic Ocean. The community need for such an aerosol product is urgent since it fills the aerosol data gap in regular MODIS products, which can only retrieve aerosol in the clear sky and on a larger scale (i.e., 3X3 or 10X10 km). Such a 'truth in truth out' study can validate the instrument performance, improve retrieval algorithm, and investigate the potential uncertainties in the retrieval product. This method is beneficial, especially in future satellite missions. Overall, this is a well-written paper with a clear description of the data and methods, and the results are presented and discussed in an appropriate and concise manner. This paper should be accepted essentially with one major comment and few minor revisions discussed below.

Major comment:

One potential uncertainty in aerosol retrieval comes from the aerosol model, especially the single scattering albedo (SSA). The MOD06ACAERO algorithm uses the standard MODIS dark target aerosol model. However, this SSA is higher than the ORACLES campaign reported values (Pistone et al., 2019). In a recent GRL paper by Chang et al. 2021, they compared the MOD06ACAERO product with their own MODIS above cloud AOD retrieval and many other observations (e.g., HSRL2, 4STAR) from the ORACLES campaign. And they found that the difference in SSA is a major source of uncertainty in above cloud aerosol retrieval. What is the spectral SSA in the dark target aerosol model, and how it compares to G5NR SSA and real SSA measured from the filed campaign? The correlation between MOD06ACAERO and G5NR ACAOD can be high as long as both aerosol models are similar to each other, but this doesn't mean they are accurate or close to the observations. Therefore, the authors need to address this problem in the paper. And for any algorithm development study, a validation by real observations would be helpful.

Differences in SSA (aerosol model) are of course the primary source of uncertainty/biases in retrieved above-cloud AOD (Meyer et al, 2016). That said, one of the main objectives of this study is to advise model developers on assimilation constraints for MODACAERO retrievals. The second objective is examine MOD06ACAERO performance on synthetic data with known truth, whatever that truth happens to be. Detailed comparison of aerosol models used by MOD04_DT (and MODACAERO) and the ones used by GEOS-5 was performed in Wind et al

(2016), which is listed as a companion paper to this one. Therefore authors did not feel it necessary to repeat the study. But, as the reviewer points out, biases/uncertainties may be present when MODACAERO is running on real data. Estimates of the aerosol model uncertainty are included in the pixel-level retrieval uncertainty reported by the MODACAERO algorithm, and we use that uncertainty to screen the pixels in order to inform data assimilation.

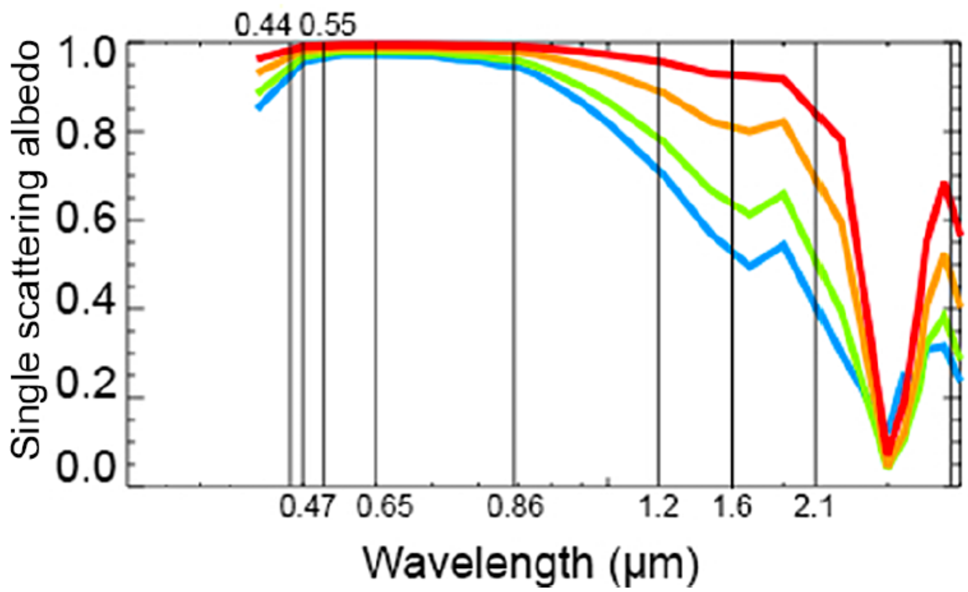

Figure 9. OPAC single scattering albedo as a function of humidity (color) and wavelength. The various relative humidity levels are in order (red, orange, green, and blue) for 95, 80, 30, and 0 % column relative humidity.

Figure from Wind et al, 2016 showing the MCARS single scattering albedo for absorbing aerosols, which is a dynamic function of column relative humidity. MOD04_DT and MODACAERO use the absorbing aerosol model at constant humidity of 80% (orange line in this plot).

Specific comments:

1. Please add color bars to figures 4-10.

Done. Thank you very much.

2. Line 71: Reference is missing as authors marked in the text.

Corrected. Thank you very much.

3. Line 96: The reference Redemann et al. 2019 may not be appropriate. Consider citing the ORACLES overview paper by Redemann et al. 2021.

Corrected. Thank you very much.

4. Line 110: In MCARS simulation, is instrument measurement uncertainty also accounted?

The instrument measurement uncertainty is accounted for as if it were MODIS instrument. It is explicitly accounted for during retrieval and is a component of overall uncertainty by which the retrievals are screened for statistics in figures 4-10. ACAERO uncertainty components are described in detail in Meyer et al (2013, 2015). There is no additional explicit uncertainty source in this particular MCARS simulation. MCARS has a capability of utilizing various real instrument characteristics, including real band uncertainty models. Looking at simulating various types of instrument uncertainty and measurement degradation impact on retrievals is a planned future study.

5. Line 118: Increase the number of streams will increase the accuracy of simulated radiance. Meanwhile, the computational time also increases, but how much more accuracy gain due to this change?

It is a fact that increasing the number of streams leads to better resolution of cloud phase functions specifically. Unfortunately even temporarily increasing resolution to 64 streams did not resolve MODACAERO retrieval issue around the cloud bow. Authors of the MODACAERO algorithm plan further study of that particular area of retrieval space. Such investigation is outside the scope of this study. Here we highlight the issue and check a couple of so-called low-hanging fruits, computational resolution being one of them. Due to increasing power of available computational resources, we made the decision to increase the MCARS resolution from 16 streams to 32, without increasing the wall-clock-time. The authors had been previously told that 16 streams is insufficient for good representation of clouds. MOD06 and MODACAERO forward lookup tables are computed at 64 streams, with MOD06 additionally utilizing the phase function directly to compute the single-scattering component of reflectance.

6. Line 136: It will be great to compare with the field campaign data (e.g., NASA ORACLES).

Indeed, and this will be a future focus of the authors of MODACAERO algorithm, especially so that now MOD06ACAERO is an official publicly available MODIS and VIIRS product. This particular study was performed in order to inform model developers as for best practices for *assimilation of MODACAERO as it presently stands, as there is a significant amount of interest in the modeling community in assimilation of MODACAERO data. This study also serves to inform MODACAERO developers as to presence of any systemic issues in the algorithm, such as a closure issue. With the exception of cloud bow issue, there does not appear to be one. Armed with that information, the authors of MODACAERO would be able to better evaluate the performance of their algorithm when comparing to ORACLES in-situ measurements.*

7. Line 270: 'from' is used twice, please delete one.

Corrected. Thank you very much.

References:

Chang, I., Gao, L., Burton, S. P., Chen, H., Diamond, M. S., Ferrare, R. A., et al. (2021). Spatiotemporal heterogeneity of aerosol and cloud properties over the southeast Atlantic: An observational analysis. Geophysical Research Letters, 48, e2020GL091469. https://doi.org/10.1029/2020GL091469

Redemann, J., Wood, R., Zuidema, P., Doherty, S. J., Luna, B., LeBlanc, S. E., Diamond, M. S., Shinozuka, Y., Chang, I. Y., Ueyama, R., Pfister, L., Ryoo, J.-M., Dobracki, A. N., da Silva, A. M., Longo, K. M., Kacenelenbogen, M. S., Flynn, C. J., Pistone, K., Knox, N. M., Piketh, S. J., Haywood, J. M., Formenti, P., Mallet, M., Stier, P., Ackerman, A. S., Bauer, S. E., Fridlind, A. M., Carmichael, G. R., Saide, P. E., Ferrada, G. A., Howell, S. G., Freitag, S., Cairns, B., Holben, B. N., Knobelspiesse, K. D., Tanelli, S., L'Ecuyer, T. S., Dzambo, A. M., Sy, O. O., McFarquhar, G. M., Poellot, M. R., Gupta, S., O'Brien, J. R., Nenes, A., Kacarab, M., Wong, J. P. S., Small-Griswold, J. D., Thornhill, K. L., Noone, D., Podolske, J. R., Schmidt, K. S., Pilewskie, P., Chen, H., Cochrane, S. P., Sedlacek, A. J., Lang, T. J., Stith, E., Segal-Rozenhaimer, M., Ferrare, R. A., Burton, S. P., Hostetler, C. A., Diner, D. J., Seidel, F. C., Platnick, S. E., Myers, J. S., Meyer, K. G., Spangenberg, D. A., Maring, H., and Gao, L.: An overview of the ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS) project: aerosol–cloud–radiation interactions in the southeast Atlantic basin, Atmos. Chem. Phys., 21, 1507–1563, https://doi.org/10.5194/acp-21-1507-2021, 2021.

Pistone, K., Redemann, J., Doherty, S., Zuidema, P., Burton, S., Cairns, B., Cochrane, S., Ferrare, R., Flynn, C., Freitag, S., Howell, S. G., Kacenelenbogen, M., LeBlanc, S., Liu, X., Schmidt, K. S., Sedlacek III, A. J., Segal-Rozenhaimer, M., Shinozuka, Y., Stamnes, S., van Diedenhoven, B., Van Harten, G., and Xu, F.: Intercomparison of biomass burning aerosol optical properties from in situ and remote-sensing instruments in ORACLES-

2016, Atmos. Chem. Phys., 19, 9181–9208, https://doi.org/10.5194/acp-19-9181-2019, 2019.

We added the suggested references. Thank you very much.