

# ***Interactive comment on “Above Cloud Aerosol Optical Depth from airborne observations in the South-East Atlantic” by Samuel E. LeBlanc et al.***

**Anonymous Referee #1**

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The paper written by Samuel LeBlanc et al. presents the Above-Cloud AOT (ACAOD) measured by the 4STAR instrument during the September 2016 deployment of the ORACLES. The magnitude, the variability and the spatial distribution of the ACAOD and the Angstrom Exponent (AE) are analysed. The results are consistent with the location of the plume observed by satellites and the large AE values above clouds confirm the presence of small particles, linked to biomass burning. The spatial variation of the 4STAR ACAOD is compared with the clear-sky fine mode AOD and ACAOD retrieved from MODIS. Then, the vertical distributions of the measured ACAOD and AE are analysed, revealing the variability of the biomass burning plume position. For one vertical profile, the 4STAR measurements are compared with other instruments on-board the P3 aircraft, including CO concentration and extinction from in-situ measurements.

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Finally, the distance between the aerosol layer and the cloud top is analysed and compared with previous satellite-based studies. The paper is clearly written and generally well-presented.

However, while the authors explain the spatial, vertical and spectral dependence of the measurements, I regret the absence of interpretation of the differences observed between the aircraft measurements and the satellite retrievals. As shown in the manuscript, the 4STAR ACAOD is found to be systematically lower than the satellite observations. Is the fine-mode AOD retrieved in clear-sky a good proxy for the ACAOD? Can the difference be explained by the contribution of the boundary layer to the MODIS fine mode AOD? Are the differences with MOD06ACAERO around 7W related to the variability of the AE observed by 4STAR? How does the AE of the MOD06ACAERO aerosol model compare with 4STAR? I also suspect the SSA of the MODIS aerosol above cloud model to have a key role in the ACAOD retrieval. Deaconu et al. (2017) have shown that aerosols within the clouds have an impact on the ACAOD retrieved from POLDER. Could it be the same with MODIS? Is there a correlation between the presence of an aerosol-cloud gap and the 4STAR/MODIS above-cloud differences? The aerosol-cloud gaps observed by 4STAR are compared to studies based on multi-year regional analysis of spaceborne lidars. Are the profiles sampled by the P3 representative of the South East Atlantic? ...

In my opinion, a discussion about the possible sources of discrepancies would be a valuable addition to this study, and I would recommend it for publication if this is addressed.

Specific remarks:

Page 2, lines 39-41: in the paper from Wen et al., the “cloud adjacency effect” describes the biases in the clear-sky AOD retrieved from passive satellites in-between clouds due to 3D contaminations. I am not sure how this applies to the aerosol above cloud retrievals. To my knowledge, the impact of 3D cloud effect on the ACAOD retrieval is

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discussed in Peers et al. (2015) and Cornet et al. (2018). Also, the reference to Wen et al. (2007) is missing from the list.

Page 6, lines 1-7: which one of the two aerosol model assumptions is selected here? The MOD06ACAERO retrieval provides an estimation of the uncertainty. Also, the ACAOD retrieved by MODIS is expected to be less accurate for small cloud optical thicknesses (COT). Do the authors use any filters for the ACAOD based on the uncertainty or on the COT? This could have an impact of the results shown in figure 8.

Page 12, section 3.4.1: why did you use AOD profiles instead of extinction?

Page 12, section 3.4.2: it is worth stating in the text that the AE at a certain altitude represents the aerosol column located above this altitude. Is the AE calculated on the average AOD observed at that altitude, or is it an average of the observed AE? Does this include take-off and landing profiles in Walvis Bay? If this is the case, the AE profile from figure 10 tends to be overly representative of the aerosol variability in Walvis Bay. Also, I am surprised that the above-cloud AE profile stops at 4000m since the ACAOD profiles from figure 9 show the presence of aerosols until 6000m. Is it because the AOD is never larger than 0.1? For the “all data” profile, there are significantly more observations above 3000m than for the “above-cloud” profile, suggesting that most of the aerosol observations comes from clear-sky measurements. Unless the clear-sky profiles have been typically performed at different locations from the above-cloud profiles, I do not really understand why aerosols would be more frequently observed at higher altitudes in clear-sky than above clouds as I presume that the presence of aerosols at that altitude is not correlated to the absence or presence of clouds. Do you have any explanation?

Page 14, lines 17-19: it is also the location associated with the largest range. Could the maximum gap extents be due to a specific event, that may have been sampled on consecutive days?

Technical corrections:

Page 1, lines 40-41: "The peak ACAOD expected from long term retrievals ..." I think this is a bit misleading, as one might think that this is the peak in the whole SEA region, while it is the peak observed along the routine flight path.

Page 2, line 20: "... the impact of these aerosolS ..." Page 2, lines 21-22: "... from satellite measurements, where the ACAOD ..." Page 2, lines 23-26: I understand that the paper is about the ORACLES measurements, but I would expect the authors to mention CLARIFY and AEROCLO-sA somewhere in the introduction.

Page 4, line 35: "... cloud DROPLET number concentration ..."

Page 5, lines 6-8: apparently, the dry absorption is not corrected for humidity. What is the expected impact on the extinction?

Page 6, lines 37-39: do the measurements used here correspond to straight level run and/or vertical profiles between the cloud top and the aerosol layer? How is define a sample (see y-axis of fig. 3 and 6)? Does it correspond to measurements performed over a certain distance/time?

Page 7, lines 2-3: what is the maximum value of the ACAOD measured by 4STAR at 501 nm?

Page 7, lines 13-15: this sentence seems to imply that satellites would indifferently retrieved AOD in clear-sky and above clouds. Also, considering this formulation, it would be interesting to actually compare with the statistic obtained from MODIS.

Page 9, line 35: is the AE calculated from averaged AOD or is it averaged AE calculated on single measurement of the AOD?

Page 11, line 28: "... MOD06ACAERO ..."

Page 12, lines 21-22: "... the far-from-coast versus profiles along the routine diagonal." Isn't it the same thing?

Page 13, lines 10-11: "... with minimal change in AOD being observed above that

altitude." Page 13, line 35: it might be useful to plot the relative humidity profile as well.

Page 16, line 22: "... throughout ..."

## References

Deaconu, L. T., et al. "Consistency of aerosols above clouds characterization from A-Train active and passive measurements." *Atmospheric Measurement Techniques* 10.9 (2017).

Peers, F., et al. "Absorption of aerosols above clouds from POLDER/PARASOL measurements and estimation of their direct radiative effect." *Atmospheric Chemistry and Physics* 15.8 (2015): 4179-4196.

Cornet, C., et al. "Cloud heterogeneity effects on cloud and aerosol above cloud properties retrieved from simulated total and polarized reflectances." *Atmospheric Measurement Techniques* 11 (2018).

Wen, G., et al. "3D aerosol cloud radiative interaction observed in collocated MODIS and ASTER images of cumulus cloud fields." *Journal of Geophysical Research: Atmospheres* 112.D13 (2007).

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