Anonymous Referee #1

First, authors would like to thank the reviewer for his/her interesting suggestions. We believe they clearly helped to bring important details on the analyse, to clarify different aspects of our findings and to better fit with the ACP scope. We did our best to improve the paper and to respond to the reviewer questions.

In the following, authors answer to the reviewer and list modifications made to the paper.

"Aerosol and cloud properties in the Namibian region during AEROCLO-sA field campaign: 3MI airborne simulator and sun-photometer measurements." by Chauvigné et al. presents the OSIRIS products such as aerosol optical depth and single scattering albedo obtained during the AEROCLO-sA airborne experiment. The presentation takes the form of histograms of individual variables, comparisons to reference observations and scatter plots between pairs of variables.

The paper, as it is, provides not so much science as retrieval results. Deeper analyses and discussions would be suitable. For example, no explanation is given for the variability in the above-cloud SSA (between 0.75 and 0.95) (Line 331). What kinds of measured radiance spectra yield the low and high SSA values? Discussion is insufficient as to why the average SSA values, given only for two of the five flights, are judged similar to each other despite the 0.02 difference. It is also unclear in what logic the supposed similarity suggests the competing effects counteracting the meteorological variation. Doesn't the similarity rather suggest uniform source or retrieval inflexibility?

Main answer:

As also recommended by the reviewer 2, the text has been modified in order to highlight the main scientific goal of the study, which is now the quantification of the direct radiative effect of above cloud aerosol (AAC DRE) over the SEA region. This is a major source of uncertainties between the climate models (Stier et al., 2013) and, so, the estimate of the AAC DRE is one of the main scientific questions that the researchers involved in the ORACLES, CLARIFY and AEROCLO-sA field campaigns try to solve. The main structure of the manuscript remains unchanged since the complete characterisation of aerosol and cloud properties is necessary to estimate the DRE. At this occasion, uncertainties on the above cloud DRE have been evaluated and added. For the aerosol parameters, the DRE errors budget is based on the observational uncertainties obtained from the comparisons performed between the different sensor included in AEROCLO-sA and from other previous observations provided for instance during the ORACLES field campaign. We think that this approach allowed to implement a realistic and rigorous DRE errors budget. A sensitivity study for the DRE and additional discussions were also included. In addition, as recommended by the reviewer 1, the discussion on the absorption property retrieved from OSIRIS has been clarified.

Here below, we investigate the different points of the reviewer's comment.

> For example, no explanation is given for the variability in the above-cloud SSA (between 0.75 and 0.95) (Line 331).
>
> **Answer:**
>
> First, we agree that the analysis of our results obtained for the aerosol single scattering albedo (SSA) was not clear enough. Histogram of the SSA has been replaced by boxplot showing percentiles, median and mean values for each flight as shown by **Figure RC1.1**. The figure shows that the range of above-cloud SSA is in fact narrower than previously expected. Values of SSA smaller than 0.82 and larger than 0.93 are not statically representative and can be considered as outliers. Airborne remote sensing of aerosol properties remains an experimental work and this is not surprizing that a tiny percentage of our retrievals may have not reached the expected quality despite of the use of quality filters.

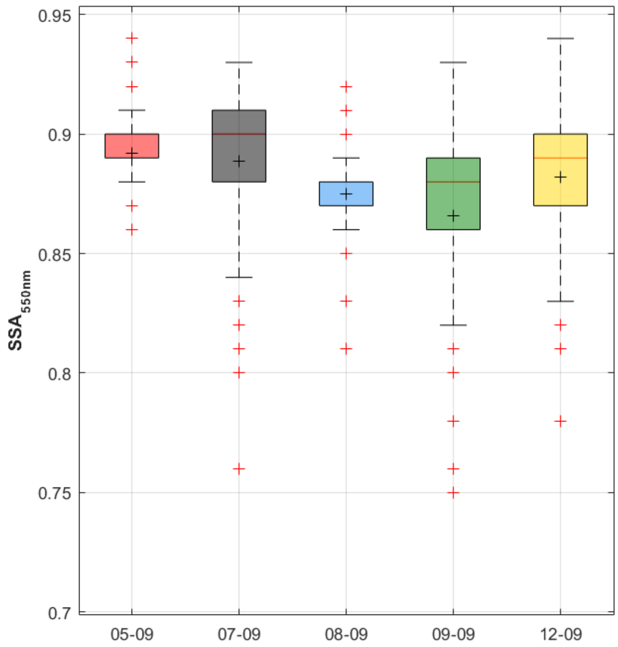

Figure RC1.1: Boxplot of the Single Scattering Albedo from OSIRIS measurements at 550 nm for the 5 selected flights.

Modifications:

l.384: “SSA values below 0.82 at 550 nm can be considered as outliers in our study. The highest and lowest absorption (and conversely the lowest and highest SSA) are retrieved respectively on 9 September (mean SSA of 0.86 at 550 nm) and on 5 September (mean SSA of 0.89 at 550 nm). This low variation in the retrieved SSA of particles suggests rather uniform sources of BBA emissions, during the AEROCLO-sA campaign time scale.”

l.534: “This suggests the BBA aerosols sampled were associated with rather homogenous sources at least at the time scale of the AEROCLO-sA airborne campaign”

Figure 9a has been changed to boxplot format.

What kinds of measured radiance spectra yield the low and high SSA values?

Answer:

The spectra observed for both polarized and total radiance are multiple and complex for AAC scenes and does not only depend on the SSA value. For the total radiance, and for a fixed value of above cloud scattering optical thickness, increasing the imaginary part of the complex refractive will reduce the SSA and consequently the absolute value of the total radiances (attenuation effect). This effect will also increase the relative differences between the measured spectral radiances (the so-called “color effect” linked to the change in the apparent color of the cloud due to increasing BBA absorption). However, this latter effect largely depends on the brightness of the below cloud layer. Different combination of COT, AOT and SSA may lead to rather similar spectra for the total radiance.

The measured radiance spectra is not the only physical effect that controls the retrieval of the above-cloud SSA in our algorithm. The retrieval of the above-cloud SSA depends also largely depend on the spectral polarized radiances and on their directional behaviours (see Figure 2 in the manuscript). Polarization measurements are mainly sensitive to the scattering aerosol optical thickness and to the change in the fine mode particles size, which also controls the SSA.

Discussion is insufficient as to why the average SSA values, given only for two of the five flights, are judged similar to each other despite the 0.02 difference.

Answer:

A change of 0.02 in the SSA is not significant since it is below our retrieval's uncertainties for this parameter. We recall that the uncertainty associated with the AERONET sun photometer retrievals cannot exceed 0.03 for the SSA. The retrieval of the SSA is very difficult but the estimate of the uncertainties associated with this parameter also remains a difficult task. This is mainly because this parameter cannot be directly measured and its estimate requires assumptions.

Inter-comparisons of various SSA estimates is probably the best way to currently reduce the variability associated with this parameter. As in Pistone et al., 2019 (ACP), we performed an inter-comparison of SSA retrievals performed from multiple instruments: airborne polarimeter from NASA (airMSPI), LOA (OSIRIS) and CNES spatial polarimeter POLDER. An excellent agreement of 3% was found between these different estimates that brings confidence in the evaluation of this highly uncertain and key parameter at least for the region and time period considered in the present study.

We added a sentence in the abstract to underline this important result, which is obtained by the inter-comparison of data provided by different instruments, teams and field campaigns.

Modifications:

l.34: "During the AEROCLO-sA campaign, the average Single Scattering Albedo (SSA) obtained by OSIRIS at 550 nm is 0.87 in agreement within 3% on average with previous polarimetric-based satellite and airborne retrievals.".

It is also unclear in what logic the supposed similarity suggests the competing effects counteracting the meteorological variation.

Answer:

We agree with the reviewer. Our sentence was unclear and misleading. Considering the small variability observed in our above-cloud SSA retrievals, and considering also that the time duration of the AEROCLO-sA airborne field campaign was only one week, we now conclude that our observations indeed rather suggest a uniformity of the sources of BBA emissions, at least at the scale of the airborne AEROCLO-sA field campaign.

Modifications:

l.387: "This low variation in the measured particles absorption suggests rather uniform sources of BBA emissions, during the AEROCLO-sA campaign time scale."

Doesn't the similarity rather suggest uniform source or retrieval inflexibility?

Answer:

We want to make clear that this is not an issue of retrieval inflexibility.

A similar methodology as the one used in the present paper was previously applied to the data provided by the POLDER spaceborne sensor (Peers et al., 2015). The method was able to distinguish between strongly absorbing biomass burning aerosols, boreal biomass burning aerosols, with rather scattering properties, and strong events of mineral dust above clouds transported from the Sahara. The method allowed to estimate different particles size and SSA values ranging between 1 and 0.8, which clearly shows that the retrieval technic is flexible and sensitive to the changes in the aerosol properties.

A more careful analysis for the AOD comparison would be nice too. In Line 246 the stratosphere is included in the PLASMA2 AOD but excluded from the OSIRIS. Can the stratospheric AOD value be estimated, for example from the PLASMA2 observations at the highest altitudes? Subtracting it from the low-altitude PLASMA2 observations may result in even better agreement with OSIRIS for the three days other than September 5.

Answer:

Indeed, PLASMA2 measurements includes the whole atmospheric column located above the aircraft. Possible high-altitude aerosols are thus observed from PLASMA2 measurements. However, this has already been considered in our comparison by subtracting PLASMA2 measurements at high altitude to PLASMA2 measurements at low altitude for the comparison. This point has been clarified in the text.

Modification:

l.211: "PLASMA2 measurements performed at high altitude allowed to characterize the residual columnar AOD above the aircraft. This quantity was subtracted to PLASMA2 AODs measurements performed at low altitude for the sake of comparison with OSIRIS retrievals. Because PLASMA2 does not allow to perform almucantar measurements as AERONET Sun-photometers, the fractions of fine and coarse mode AOD was derived from the PLASMA2 spectral AOD measurements using the Generalized Retrieval of Atmosphere and Surface Properties (GRASP) algorithm (Dubovik et al., 2014). GRASP also allows to retrieve the volume size distribution from spectral AODs (Torres et al., 2017), assuming a complex refractive index (i.e. 1.50+0.025) and a bimodal lognormal particles size distribution with fixed modal widths."

Discussion on the apparent AOD-H2O relationship (Line 350) should address cloud contamination. Thin clouds can be mistaken as high AOD and are often coincident with high water vapor. How much of the data shown in Figure 10 were taken under clouds? How did you determine that?

Answer:

Optically thick clouds are automatically excluded from measurements due to PLASMA2 inability to track the Sun. If optically thin clouds are included in our measurements, the retrieved Angström exponent should clearly demonstrates the presence of cloud droplets above the Sun-photometer with $\alpha_{533\text{-}855}$ values below 1.2 (Roelofs and Kamphuis, 2009). However, PLASMA2 $\alpha_{440\text{-}870}$ do not show values below 1.8, which is typical of fine mode aerosol as shown by **Figure RC1.2**.

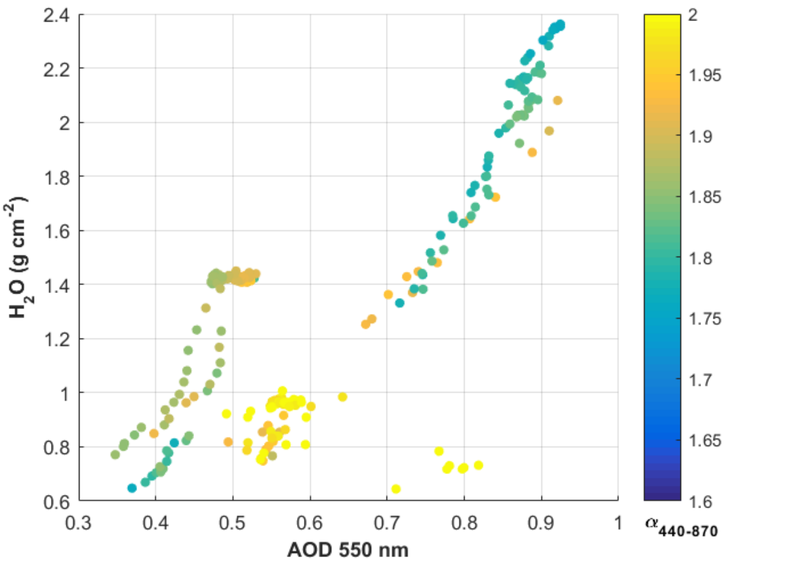

Figure RC1.2 : Column water vapour in function of AOD and Angström exponent retrieved from PLASMA2 measurements.

As for the comparison of the calculated DRE values with other estimates, cloud fraction and intentional sampling bias should be mentioned in the place where the comparison is described (Section 4.6), without waiting until Lines 446 and 443. It is worth explaining and emphasizing why these two factors weaken the usefulness of the comparison.

Answer:

We mentioned in this section that the OSIRIS DRE estimates were performed for full cloudy scenes (at least at the scale of the OSIRIS image: 20 by 20 km^2) and cloud fraction lower than 1 would have led to lower DRE.

We recall that the south-east Atlantic Ocean was overlaid by one of the planet's major stratocumulus cloud deck for the considered time period and that cloud cover with high fractional cloud cover is frequent. 75% of the cloudy scenes sampled with OSIRIS were associated with a geometrical fraction of 1, which is not surprising for the considered area.

The DRE estimates performed with POLDER and SCIAMACHI sensors by De Graaf et al. (2019) were performed for full cloudy scenes for POLDER for COT larger than 3. and for scenes with fractional (effective) cloud cover for SCIAMACHY larger than 0.3 and COT larger than 3.0. So, the DRE comparisons performed between OSIRIS, SCIAMACHI and POLDER DRE are not so inconsistent, in terms of sampled cloud covers.

Indeed, above cloud instantaneous DRE retrievals in a more complex environment (lower fraction of cloud cover and thinner clouds) needs additional information as cloud fraction and cloud microphysics. Comparison between sensors will also be completed by an analyse on the impact of the spatial resolution, which could affect the DRE. These as been re-demonstrated recently on the works of Cochrane et al. (2019) and De Graaf et al. (2019b) respectively, and present interesting analyses for further works.De Graaf et al. (2019b) have merged several satellite measurements with different spatial resolutions. Low resolution smooths signal and ignore under-pixel variation of the cloud albedo, which tends to lead to underestimation of cloud fraction and cloud albedo, whereas high resolution can under-estimate 3D-effects at the edge of the clouds.

We also added a discussion in the manuscript to allow to the reader the possibility to appreciate the differences observed between OSIRIS, POLDER and SCIAMACHI DREs, with regards to the spatial resolution of each sensor.

Modifications:

More details have been added to the DRE discussion.

l.44: “The high absorbing load of AAC combined together with high cloud albedo leads to unprecedented DRE estimates, higher than previous satellite-based estimates. The average AAC DRE calculated from the airborne measurements in the visible range is +85 W m^{-2} (standard deviation of 26 W m^{-2}) with instantaneous values up to +190 W m^{-2} during intense events. These high DRE values, associated with their uncertainties, have to be considered as new upper cases to evaluate the ability of models to reproduce the radiative impact of the aerosols over the South-East Atlantic region.”

l.474: The whole DRE discussion has been clarified: “These mean DRE are higher than previous retrievals in the region. […] The relative low aerosol loading observed on 12 September (AOD of 0.12-0.18 at 865 nm) are still associated with significant values of DRE (+65 ± 25 W.m-2 on average) mainly because of the high COT (20-30) retrieved on 12 September.”

We thank the reviewer for the below corrections.

Minor suggestions follow.

Line 3 Remove the period.

L. 16 Remove the first "of".

L. 22 Spell out AAC.

L. 25 Don’t spell out AAC.

L. 27 "show" should precede "a".

L. 44 Replace telluric with terrestrial.

L. 95 "coexist" should read "coexists".

L. 105 Sect. 4 should read Sect. 5.

L. 119 Put "m" after 15.

L. 120 Remove the vertical bar.

L. 133 "the" should precede "airborne".

L. 140 "wild" should read "wide".

L. 149 Did you mean to put "a" before "few"?

L. 184 Put "to" after "referred".

L. 190 "overcoast" should read "overcast".

L. 261 The backscattering of 1.10-6 m-1sr-1 is not necessarily low. Shinozuka et al. (2020) used a threshold one fourth as large to identify smoke. How about noting the value under which 95% of the Sept 12 data reside, instead of 100%?

Indeed, it was a mistake to take this value as a reference. Because there is no need for this ABC value here, it has been removed.

L. 346 Drop s from "coasts".

L. 355 End the sentence with a period after "area". Capitaliza b in "biomass".

L. 406 Insert "horizontal" before "resolution".

L. 411 Put an s to "contribute".