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Atmospheric Chemistry and Physics Discussions

# *Interactive comment on* "Evidence of the complexity of aerosol transport in the lower troposphere on the Namibian coast during AEROCLO-sA" *by* Patrick Chazette et al.

**Anonymous Referee #2**

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The manuscript describes observations from ground-based and airborne lidar, sunphotometer, and dropsondes made during the AEROCLO-sA field campaign on and near the Namibian coast. Data analysis is aided by coincident satellite observations, HYSPLIT back-trajectory analysis and two additional models. These data and analysis are used to illustrate the vertical distribution and the spatial and temporal variability of the aerosol amount during the campaign. A finding of the paper is that while most of the aerosol is of African origin, a portion has been transported long distances from South America.

General comments



The manuscript is interesting and generally easy to read, although the organization of sections 3 and 4 could be made to flow better. The clear organization in the introduction and the conclusions sections were particularly appreciated. The paper includes appropriate acknowledgement of prior work.

On the other hand, I find that some of the conclusions, both major and minor, are overinterpreted, that is, drawn from slight evidence that is not well supported or should be understood to have high uncertainty.

The argument that the South American aerosol layer is "distinct" is unconvincing and the conclusion that it is of significant importance for climate modeling is premature. Yet, aerosol transported from South America to Africa is still interesting enough to highlight, even without this. Better to be very straightforward about what is and is not known about it, to inform and motivate future study.

Additionally, some lack of clarity makes it difficult to understand the details of the lidar retrieval; in particular the derivation of the lidar ratio, and the associated uncertainties. The lidar retrieval is subject to large uncertainties because of the underdetermined nature of the problem, but there is a lack of useful information about the size of the uncertainties or their impact on the conclusions.

Specific comments

119 "between about 1 and 4 hours". Actually, several of these averages are 7 or 8 hours long, so this should be indicated correctly. Even 4 hours seems like quite a long time, considering the variability of aerosol in the region. Was there any need for filtering or any analysis to check for stationarity?

Section 2.3 The Bruneau et al. 2015 paper referenced at 135 is missing from the bibliography. I think I know which paper you mean, though, and it says this instrument has HSRL capability at 355 nm. If so, why does it require the retrieval procedure that's used for the ground-based elastic backscatter lidar? Even if I'm wrong about the HSRL,

the appendix says that the lidar has a 355 nm channel. So then why is the 355 nm data not shown in figures 6b and 8b? (if it's available, it would be very helpful there!)

Section 3. I found the organization of section 3 hard to follow. It goes back and forth multiple times between different subjects. Please consider reorganizing to make one paragraph about the overall AOT trend, one comparing P1 to P2, and another separate paragraph comparing P2 to P3.

215-218 statement that lidar ratios in the free troposphere "suggest the presence of terrigenous aerosols mixed with smoke. This is coherent with the polluted dust type inferred from the CALIOP observations." Is this circular reasoning? The Appendix suggests that only the lidar ratio in the PBL is retrieved and that the lidar ratio in the free troposphere is taken directly from the inferred lidar ratio in CALIPSO or CATS.

The presence of dust in the smoke layer isn't very consistent with the AEROCLO-Sa ground-based lidar measurements in Figure 3, which shows quite small values of the particle depolarization ratio within the smoke plume for all profiles.

Even if I'm misunderstanding how the constrained retrieval works on the ground based lidar, I believe it's likely that the retrieved lidar ratio in the free troposphere must have a large degree of uncertainty which probably precludes making a distinction between smoke and polluted dust, whereas the uncertainty on the particle depolarization ratio is likely to be quite reasonable. Does this conform to your analysis of systematic errors and uncertainties?

220 "being remobilized by pyroconvection and mixed with BBA before being transported aloft". How do you know these details about the origin of the dust? What evidence is there of pyroconvection?

217 What does the citation Flamant et al. 1998 refer to here? Is this a typo? (Also, the paper is missing from the bibliography).

232 "LR values in the FT evolving from 55 to 70 sr". I believe the lidar ratio in the



free troposphere is assigned based on aerosol type that is somehow inferred from the CALIPSO and CATS aerosol type inferences. It would be better, then, to directly refer to a change in inferred aerosol type rather than an evolution of the lidar ratio, which implies more quantitative detail than is actually available.

238 "LR values observed in the PBL". Please be specific about which retrieval you mean. The combined lidar-sunphotometer retrieval or the sunphotometer only retrieval from the previous sentence?

239 Again the presence of dust would be expected to be accompanied by an elevated particle depolarization ratio which is not evident.

245-247 The relatively high particle depolarization ratio in the altitude region between the smoke plume and the PBL seems unlikely to be significant compared to its uncertainty. The systematic error of particle depolarization ratio increases dramatically for low backscatter ratios (see, e.g. Freudenthaler et al. 2016, Burton et al. 2015). If you have done a calculation of the expected systematic uncertainty and believe these to be significant, then that should be included to support your interpretation.

Table 3 What is the number after the plus-and-minus sign?

Table 3 Why is the lidar ratio consistently only a few different values? In the PBL, the retrieval is described as a constrained retrieval, so I expected it to be able to take a continuous range of values.

Figure 3 Add error bars? I expect significant amount of variability due to the very long averaging and also a significant amount of systematic uncertainty. Even if only a coarse estimate of systematic uncertainty can be included, this would be valuable for interpreting the significance of features in the profiles.

316ff. Somewhere in this paragraph please state the distance between the profiles.

318 "operate at different wavelengths". Table A1 indicates that LNG also operates at 355 nm. Can you show 355 nm retrievals from LNG as well? It might help establish

that there really is correspondence between the airborne and ground-based retrieved extinction and give better support that the differences are not due to the wavelength.

324 "the difference can be explained". There are multiple factors affecting this difference, including the approximately four hour time difference between the profiles, which has not been addressed. Any comment about the role of the time difference? In any case, soften the statmeent. Maybe "More important is the regional scale circulation"

328-329. Does the CAMS model also show this difference between the aerosols over the land and ocean? You previously made an apparently conflicting point that CAMS indicates homogeneity in the aerosol around Henties Bay.

335-336 "the structure of [profile 2] being coherent with the ground-based AEC profile". Not convincingly so. Also, this statement is apparently contradicted at line 347. Is this a typo?

340-341 I'm confused by the indiation of 20% RH above the BBA layer. First, is this referring to 9b or 9a? Either way, I see that it doesn't drop dramatically to zero like 8b, but I do not see 20% RH for any part of the profile above the strongest gradient (top of the BBA) and even the highest value I do see (more like 10%?) is only for a few hundred meters.

341-342 "suggests the presence of a distinct aerosol layer". Is the key point that there is aerosol present? In which case, I think the lidar profile itself (assuming the signature of the aerosol is significant above the retrieval uncertainty and not just an artifact of the retrieval) is evidence of aerosol and the RH is mostly irrelevant. Or is the key here that the aerosol is "distinct". I don't understand how either the extinction profile or the relative humidity indicate that the aerosol is physically distinct from the African BBA layer.

344 I don't see that there is much agreement in the "structure" of the PBL. You might just say more simply that the apparent height of the PBL in the aerosol agrees with the



location of the gradient in RH.

353-354 Not clear what "distinct aerosol layer above the main BBA layer" means. Please specify the altitudes you're talking about. To me it looks like the main BBA layer extends to higher altitude in the Henties Bay uplooking lidar profile and in profile (1), while (2) shows a lower top for that layer. I don't see it as a separate, secondary layer. I can easily agree if you say "additional aerosol above 5 km" which is more unambiguous.

360 "related to ... hygroscopic growth ... particularly below the BBA layer where RH is high in '2'". Again, I'm having some trouble following the roundabout wording here, but I take "below the BBA layer where RH is high" to mean "below 1 km". Yet there is no enhancement of extinction in profile '2' below 1 km. So, either this statement is incorrect, or the wording is so confusing that the meaning has been lost for at least one reader.

361 How robust are the estimates of the AOT of the layer above 5 km to the uncertainties in the lidar retrieval?

362 "suggest that the aerosol may have a different origin". Again I do not understand what evidence supports this statement.

392-393 "RH values ... may be an indication of the transport of BBA from a different origin." Again, I don't understand why the RH values should be taken as evidence of a different origin. I believe you have stronger evidence in the back-trajectories. It would be better not to state this conclusion until it has actually been supported. At most, for this sentence, I would say something like that the difference in RH is an indicator that the meterology has changed (if indeed that is what you believe) and that that will be shown in the next section.

416 "are transported very rapidly" I don't understand how to interpret the figure to conclude that the aerosols are transported rapidly. Since the trajectories are more

tightly distributed around the point of origin here than in the other panels, and yet all 3 panels show back-trajectories for the same 6-day duration, I infer that in this panel they moved more slowly.

423 "They correspond to air masses arriving above 5000 m AMSL over Henties Bay". Please show this by splitting 11(c) into panels above and below 5000 m. Since you treat this point as important, it should be shown explicitly.

Figure 11 caption. What does "normalized occurrence" mean (normalized to what)? Does this imply that the scale does not translate to the same number of back-trajectory points in each of the three panels?

502 "of paramount importance" should be toned down. "Highlighting" the transported aerosol is interesting and worthwhile but not of "paramount importance" until it is shown to be climatically significant and not already captured in climate models.

750 Define "apparent backscatter coefficient", preferably using an equation. Not knowing for sure what this is is making it hard for me to follow the rest of the section.

751-752 "must follow the slope of the molecular bacskcattering". This is not well explained. Won't there be attenuation of the signal by air molecules and aerosol at lower levels? (wheras the molecular backscattering from ERA5 is not affected)?

759-760 "the error remains below 2-3%" Which error remains below 2-3%? The error in the molecular backscatter, or the aerosol backscatter derived from it, or the aerosol extinction derived from it?

779 "uncertainty sources are exhaustively quantified". Given that you have access to a methodology for quantifying the uncertainty, it should definitely be quantified for the data presented in this paper. Depending on how big the retrieval uncertainites are, some of your conclusions can be affected, as discussed elsewhere in this review, so it's not just an academic exercise.

781-782 "using aerosol typing determined from the CALIOP and CATS measure-



ments". How to you obtain the free-troposphere aerosol type and lidar ratio for cases where there is no satellite overpass in table 1? How do you get them for cases where CALIPSO or CATS or both infer multiple types in different pixels in the region (like the 31 August case, for instance).

795-798 It seems like a stretch to infer from just a few individual cases of transported smoke from a totally different source as presented by Muller et al. 2007 that the lidar ratios for dust and smoke at 355 nm are the same as 532 nm. Is this the only relevant paper?

800 "matches best the AOT from the sun photometer". At the lidar wavelength?

812 "uncertainties of 2% on the PDR". Do these uncertainties include sources of systematic error? Doesn't the uncertainty level depend strongly on the amount of aerosol? So, is there a minimum aerosol amount to get the quoted 2% error?

Minor comments

52 "as also mixes". Should this be "and also mixes"?

91 says the ground-based lidar is an ALS 300, but in the appendix it says ALS 450. Is there a difference between these two designations?

93 please indicate what type of lidar the LNG lidar is.

98 UTC is "coordinated universal time"

154-155 a better reference for CALIOP 4.10 typing would be Kim et al. 2018

175-176 "The standard deviation on the AOT" should be "the uncertainty in the AOT".

205 change word order "when aerosols are only observed"

209 refers to lines highlighted in green in the table. I don't see highlighting. Does this need to be reworded?

210 "averaged AOT of $\sim$0.15" Indicate which instrument or model this refers to.

213 reference to Angstrom exponent. Which instrument or model?

227-228 "between the 2 periods". Between P1 and P2?

234 add reference for sun photometer retrievals of lidar ratio

250 "match perfectly" is an overstatement. Please reword. It's better to be quantitative anyway.

256 "positively biased" reword to avoid "biased" and use a more neutral phrase like "larger than". You've given reasons why either the model or the observations (or both) could be incorrect in this case.

Table 3 caption, UAL is used here where elsewhere it is described by the label FT. Is the difference signficant? If not, please pick just one.

Table 3 column "AE" please indicate which instrument this is from.

Figure 2 It would be easier to understand the x-axis if tick marks were an integer number of days instead of 1.5 days.

292 "where" should be "were"

294 I believe this is probably attenuated backscatter coefficient rather than aerosol backscatter coefficient. This is an important distinction.

308 remove "wood". I think it's more likely grasses and crops here than wood, but either way it's speculation. "Combustion" is sufficient.

323 "apparition" should be "appearance"

334 "offshore airborne lidar measurements from Henties Bay". Replace with "the profile west of Henties Bay" for clarity.

351 "below the base of the BBA layer observed further south". Please simply state the altitude for easier reading.



352 "The RH above the top of the BBA layer". Again, it would be helpful to be more specific about what altitude and which RH profile you are referring to, for easier reading.

Figure 6 caption "apparent bacskcatter coefficient". Is this the same as "attenuated backscatter coefficient"? Please add a reference for where this quantity is defined.

386 add "at Henties Bay" for clarity

408 "Illustrating" not "corroborating" (this isn't independent evidence)

412 "between the 3 regimes" perhaps rather than "periods" since the different regimes include different choice of ending altitude as well as choice of ending date.

412 similarly "For the layers observed during P1" for the start of the next sentence, since you are only showing back-trajectories corresponding to observed aerosol layers.

414 "consistent" not "coherent"

484 "illustrate" or "show", not "evidence"

497 probably delete "trapped" or reword to make the meaning clearer

498 I don't understand the meaning of "in link with the dominant transport patterns of lifted aerosols". Please reword.

504 replace "fundamental" with "necessary". Fundamental has a connotation of primary importance in addition to meaning "necessary" and therefore sounds like an overstatement.

Table A1 add post-processing temporal resolution

749 Replace section title with "Overlap correction" or something similar, since this is only one of many aspects of calibration but the only one discussed.

761 "average lidar profiles".

766 replace "perfect coincidence" with "very good agreement"

777 replace "exogeneous" with "external"

798 replace "standard deviation of LRs derived from spaceborne lidars" with "expected uncertainty in LRs for spaceborne lidars". Lidar ratio is not dervied from CALIOP and CATS; they do not measure or retrieve lidar ratio. It's an input, not an output, of the retrieval.

802 replace "coherent" with "consistent"

807 replace "inverse" with "invert"

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