Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-321-RC3, 2019

Atmospheric Measurement Techniques Discussions
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Interactive comment on "Evaluation of satellite-based aerosol datasets and the CAMS reanalysis over ocean utilizing shipborne reference observations" *by* Jonas Witthuhn et al.

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Received and published: 10 November 2019

Review of paper:

Evaluation of satellite-based aerosol datasets and the CAMS reanalysis over ocean utilizing shipborne reference observations by J. Witthuhn et al.

Positives - needed demonstration of (MAN) reference data over ocean - efforts to evaluate more than just the aerosol column amount (AOD)

Concerns - shadowband (GUV) data seem to lack processing maturity to serve as reference - comparisons to two satellite data and one assimilation lack interpretation

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Discussion paper

- aerosol typing via AOD and Angstrom should be redone – more tailored of oceanic reg.

General comments

The paper evaluates the aerosol properties over oceans of two satellite retrievals (MODIS, SEVIRI) and one modeling effort (CAMS) that assimilated MODIS data. The evaluation is based on matches (in time and location) to shipborne samples of the direct solar attenuation and of solar scattering during multiple latitudinal Atlantic crossings with the German POLARSTERN research vessel. The accuracy of (handheld MICROTOPS) direct solar attenuation data is out of question and serves as the main reference in the evaluation. In contrast, the usefulness of the complementary shadowband radiometer (GUV) appears more limited (completely cloud-free situations are needed) and the retrieval algorithm to retrieve the direct solar spectral irradiance component has not reached the needed maturity (still many ad hoc adjustments are needed to match solar attenuations of simultaneous MICROTOPS measurements). Thus recent efforts to improve the shadow-band references (GUV, GUVisE) are more something for the Appendix. Focusing on the sunphotometer data there are many nice aspects addressed (although other satellite data sets and models could be included – possibly in an additional paper). I am not so happy about the chosen aerosol classification (especially since many source types like biomass are unlikely to be observed over oceans). Based on the sunphotometer data for AOD and Angstrom value (use AE only if AOD550 is larger than 0.15) I would separate into 4 categories (see comments to Figure 1) and work from there. I really like the plots that investigate biases are function of AOD. That said I am really disappointed that this detail is missed in the statistical tables, as common features of (1) AOD overestimate at lower AOD and (2) AOD underestimate at larger AOD lead the authors to claim via a linear fit 'overall good agreement' and 'low biases'. The paper is great contribution but I think it needs a major revision prior to a publication.

Detailed comments

1/17 if AE is overestimated then offer an explanation such as that large mineral dust size-events are missed or that the compositional mix is constrained by model assumptions

1/21+ the radiative effect/forcing introduction (although I am not sure if it is needed) could/should be sharper: In terms of radiative forcing (that is the impact by anthropogenic aerosol at all-sky conditions at TOA) the indirect effect RFaci overall has larger contributions than the RFari. And anthropogenic aerosol impacts are primarily caused by extra smaller aerosol sizes so that (mostly natural components) of seasalt and dust which are mainly observed over oceans are almost irrelevant even for RFari. The impact of these two components on Raci (seasalt to increase CCN, dust to increase IN) has been demonstrated but the overall impact strength remains unclear (for more on radiative effects and forcing have a look at the MACv2 paper).

2/37+ if you mean CERES (broadband radiation) data then say so, even though then the link of aerosol retrievals (they make a compositional and size assumptions to yield AOD estimates) to broadband fluxes is not straight forward and need further rad.transfer modeling.

2/39 Exactly, this is why you want the ship data: to evaluate and to test (retrieval) model assumptions.

2/55 you may also consider to evaluate to (the newly re-processed) MISR data, to VIIRS data (designated as MODIS follow on), to SLSTR (the ATSR follow-on) data and to GRASP-type (e.g. MERIS) data.

2/76 A separate evaluation for fine (and mostly anthropogenic) and coarse-mode AOD (as offered for the MICROTOPS data via the SDA approach) - in place of an Angstrom parameter evaluation - would elevate a marine aerosol retrieval or modeling evaluation: Most global models and satellite retrieval models use bi-modal (by size) scheme, while Angstrom parameters depend spectral choice and becomes extremely noisy and probably meaningless at low AOD values in already one of the two spectral bands needed.

5/131 I would have used a different description of the Angstrom parameter : ANG = - ln(AOD1/AOD2) / ln(wavel1/wavel2) . . . as the negative spectral slope in ln/ln-space

5/138 The AOD shadow-band radiometer requires more actions (leveling corrections) and is more restrictive (completely cloud-free over the time of a scan).

6/180 The empirical correction is covered in detail but only applied to the shadowband (GUV) instrument (and not to the sunphotometer). Considering that the GUV match statistics is so much sparser then for the sunphotometer (with useful data evaluation data at this stage only through sunphotometer matches) so that in the end only sunphotometer data are used in the evaluation, I wonder if all that GUV detail (table and figures) is not better added to the Appendix. In terms of the forward scattering correction I am worried about a linear approach - which ignores a dependence on aerosol size (over oceans certainly at larger AOD) size.

6/179 COMB is a subset of GUV, where GUV outliers (inconsistent to MIC) removed - correct?

7/194 mention also the AOD (I assume 550) wavelength of MODIS

7/208 there are three major solar retrieval problems for dust outflow: (1) dust is solar spectrally flat (like clouds) and large AOD events may be removed as clouds → retrieved dust AOD too low (2) dust size is underestimated and with it the size related 'dust absorption' (with low SSA values) → retrieval AOD will be too high (3) non-sphericity has increased side-scatter so that a retrieval model with coarse-mode and fine-mode spheres will interpret the extra side-scatter artificially with extra fine-mode spheres → wrong composition and likely size underestimate (see under 2).

7/219 . . . but cloud coverage may be wrong in global modeling. . .aside that the AOD might be different in clear-sky and cloud-sky regions of modeling

7/226 in CAMS only AOD is assimilated and in its bias correction the compositional mixture of the forecast model is maintained . . . so the composition may get worse (in comparison to a forecast without assimilations). By the way, the use of the (relatively sparse) ATSR data added little in a combined (ATSR & MODIS) assimilation - as the volume of MODIS data dominated.

8/228 the offered aerosol classification (based on AOD and ANG) is rather general and prone to failure if one of the two needed AOD values becomes low. For those events any ANG value becomes meaningless. And with respect to aerosol typing aerosol is always a mixture of many components. And unless surface winds are very calm, even marine aerosol has Angstrom parameters between 0.7 and 1.0. An ideal thing would be if simultaneous info on aerosol absorption would be available (as demonstrated in MACv2). To extract info an components, I would start with an AOD separation into fine-mode (r<0.5um) and coarse-mode (r>0.5um) contributions via the fine-mode AOD fraction (easily derived from the AOD spectral dependence) to separate seasalt/dust from pollution/wildfire aerosol (in a quantitative way!). The MAN data-base (where MICROTOPS data are stored) offers such derived (fine-mode-fraction) estimates!

8/230 the AE overestimate in CAMS can be just related to the improper component mixture (too much fine-mode contributions) in the forecast model, which an (total) AOD assimilation cannot fix .. and in case of AOD adjustment during the assimilation process will pull away from likely expectations (such that mix of assimilated products is often worse than that of the forecast model)

8/240 aerosol is always a mixture of many components and what the simple 'Toledano' scheme does is simply identifying a likely dominant component in a qualitative way. I disagree though that marine aerosol has Angstrom parameters larger than 1.2 unless there are contributions from pollution and or biomass burning. AE values larger than 1.2 at should be linked fine-mode aerosol with contribution from sulfate / nitrate (less absorption), pollution and aged biomass burning (medium absorption) and fresh biomass burning (highly absorption and AE >1.5).

8/245 all classes are 'mixed' . . . but in terms of the mixed category here, how useful is a ‘mixed’ category if it could be a 10/90% or a 90/10% mixture?

9/260 for more events (I think) the <22km co-location requirement could be relaxed over ocean

9/262 why only so few matches between MIC CAMS-RA (as modeling has AOD data at any location and time)?

10/298 Well it is sad that GUV retrieved AOD are often inconsistent to (trusted) MICROTOPS data – as apparent more algorithm work is needed.

10/306 To achieve GNU vs MICROTOPS consistency a rather complex procedure is applied to GNU data based on comparisons to almost simultaneous MICROTOPS samples. Hereby the described method seems a bit arbitrary to me. To account for the forward scattering into the GNU 15deg field of view (isn’t 15 deg just the width of the band so in effect the missed diffuse radiation is even larger than 15 deg?) a constant C is defined . . . while in reality this forward scattering contribution depends (at completely cloud-free conditions) on aerosol size (!) and multiple scattering potential (AOD, airmass) . . .so a constant seems a poor choice. And then there is even a second scaling factor for a temporal (do you mean sun-elevation?) correction!

12/376 a fixed bias of -0.02 (with the new processing) seems strange as I would expect a bias related to missed forward scattering to be function of AOD and size..? Actually Figure 3 shows such an AOD dependence of the bias. Generally: the entire correction explanations of 3.4 and of 4.1 (till line 400) including the comparisons of Table 4 are technical details which seem better suited for the Appendix as the focus should be on the comparison of satellite (and CAMS) data to trusted references.

12/383 . . . the forward scattering missed radiation problem is more an issue for larger size and AOD (e.g. especially relevant for larger mineral dust sizes). You actually show in Figure 3a that this bias is near zero at low AOD and stronger at larger (likely dust) AOD . . . in that sense it is misleading to talk about a -0.02 bias (but I said this before).

13/412 how was the SEVIRI AOD at 550nm derived (was the MICROTOPS Angstrom parameter used?)

13/417 The larges MODIS AOD outliers in the 0.3 bin vs GUVisE may be less meaningful since the sample number is fairly low. This raises the question, why the GUVisE data-set is so small and why this data-set only addresses selective dust and marine cases. Does it mean that the retrieval and correction method very frequently fails?

14/424 I do not see major differences between 4a and 4b unless low (and less meaningful) statistics is considered. the low GUV sample number remains a mystery to me (a few 'marine' and 'dust' cases).

14/435 you could compare if the SEVIRI AOD550 data would be different if the MICROTOPS 440/870 Angstrom had been used instead (also the SEVIRI band are spectrally much broader with some water vapor contamination especially in 810nm band).

14/439 I would say Figure 5 shows (opposite to your assessment) that SEVIRI AOD is usually higher than MODIS (at low to median AOD) and that at high AOD SEVIRI likely has a low bias, as (large AOD dust events with no solar spectral dependence) are probably removed during cloud screening.

14/445 Can you say this when samples of the two different MODIS products are different?

15/471 Why did you apply SEVIRI Angstrom and not MICROTOPS Angstrom data to interpolate from 630 to 550nm?

15/474 Why would I want to use COMB if I have MIC (and much better statistics)?

15/478 the MICROTOPS 440/870 Angstrom is more reliable than the 670/870 Angstrom. (The label in Figure 7 says 440/870 . . . but the captions say differently?). Anyway, you do make sure not to include AE data if AOD at 870nm is below 0.05 . . . otherwise derived Angstrom parameters are likely close to 'garbage'.

16/489 I agree that at low AOD satellite tend to overestimate AOD due to a more relaxed or insufficient cloud-screening (sometime there are many low clouds which are hardly visible)

16/495 the CAMS forecast model (and thus also MODIS AOD data assimilations) have a too high fine-mode fraction for the dust outflow region. I am not sure if the problem of the satellite retrievals is related to non-spherical shapes of dust: Assuming spherical shapes in retrieval models the higher side-scattering of non-spheres is compensated (then incorrectly) by an extra fine-mode fraction.

17/530 Frequently the AOD over oceans is quite stable ... as long as there are no changes in near surface winds and unless you enter/exit a big plume, as the Saharan dust outflow. Then AOD variations are much stronger than suggested here (possibly these cases were removed in this study a mixed aerosol type to not acceptable aerosol type). In particular for process studies these aerosol gradients (as few as they may be) are of interest.

17/549 the positive bias at low AOD is still there! You cannot use negative biases at higher AOD to suggest a lack of bias.

18/558 The (to MODIS) added use of ATSR data had a negligible impact, since MODIS data were dominating in volume.

18/575 I would not expect significant differences between MODIS and CAMS except that the aerosol typing (e.g. AE) becomes worse in CAMS, as AE in CAMS in model prescribed.

19/610 this is not too convincing as along as a MICROTOPS reference is needed to assure accuracy.

19/620 an important result is that AOD biases change with AOD strength

20/629 have you determined the MODIS Angstrom (if so which wavelengths) or was simply the available product from MODIS used?

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20/641 I disagree. There are biases and AOD retrievals make assumptions, which are not validated and often can be poor - affecting in turn the assigned AOD.

21/644 I agree that AERONET sky capabilities and the use of available inversion data would be great. The MFRSR type GUV however is a different approach. AERONET inversions show that sky data offer aerosol size (-distribution) detail, while info on aerosol absorption requires large AOD cases. Anyway, those inversion capabilities with GUV need to be demonstrated first.

22/... A nice touch to mention EarthCare ... although 3MI might be an aerosol satellite dedicated satellite sensor, which likely will launch and provide data sooner.

Figures and tables

table 1 nice

table 2 I would rename the categories: maritime → maritime background, mixed and continental → continental transport, desert dust → mineral dust transport. I would get rid of this biomass (near sources) component since aged transported biomass is more like continental transport. I also wonder why there are so many 'no class' events for GUVis – apparent outliers as they do not appear in COMB. It is disappointing that COM matches are only 5% compared to the MIC matches

table 3 the C-values without a few exceptions are very close to 1.0, so in effect only the lab calibration factors seem to matter (I am not sure how this V to radiance conversion was done, though). And S to correct for the forward scattering into the field of view should be a function of AOD and size (which is also a function of AOD since large dust AOD usually carry larger sizes).

table 4 I would move this into the Appendix.

table 5/6/7 Maybe all the data can be compacted into a single table. I would work with 550 nm statistics only (and use Microtops data to convert SEVIRI to 550nm). I would focus on MIC data and I would separate by 3 regions (dust outflow, continental outflow and maritime background) and there into lower and higher AOD. Also I would focus on bias and I do not know how to judge correlation. With low AOD cases (and more noise) correlations are meaningless.

figure 1 great overview. But I cannot believe a dust domination in the southern hemisphere (as for the last cruise near 8S) - unless close to the Namib. I also would separate into transported dust (AE <0.5, AOD >0.15), maritime background (AOD <0.15), continental transport (AE >1, AOD >0.15) and mixed (AE 0.5 to 1.0, AOD >0.15) unless close to the Namib. For a clearer presentation I would compare the different reference data in one plot and MIC vs satellite and CAMS in another plot

figure 2 redo with the suggested typing of Figure 1 comments

figure 3 /4 something for the Appendix (why are counts of COMB sometimes higher than for GUVisE in figure 4?)

figure 5 nice detail . . . but just because SEVIRI has likely (and missed dust event related) biases at higher AOD, while most cases (at low AOD) are larger than MODIS you cannot conclude that the SEVIRI overestimate (compared to MIC) is lower

figure 6 seeing this plot, who wants to use the Angstrom parameter from satellite remote sensing and even modeling? SEVIRI seems to use a very simple Aerosol model without allowing for large and small Angstrom parameters. Similarly CAMS is constrained by composition, which does not allow for large Angstrom parameters. On the other hand very high Angstrom parameters with MICROTOPS may be associated with low AOD. Thus I recommend to show Figure 6 only for MIC data, when AOD at 870 is at least 0.1.

Actually I call a redo of Figure 6 via a Figure 5-type plot where Angstrom data are compared as a function of AOD bins.

figure 7/8/11 I would redo the aerosol types – see comments to Figure 1 (I assume all component samples fit within circles) figure 9 interesting aspect

figure 10 nice

resource

I placed relevant monthly 1x1 lat/lon gridded data of the MACv2 aerosol climatology on ftp in ascii and netcdf (for details on file naming look at README)

ftp://ftp-projects.zmaw.de/aerocom/climatology/MACv2_2018/550nm/for_tropos/

there you find expected monthly average for the 450nm/850nm Angstrom parameter and aerosol single scattering properties at 450, 550, 650 and 850nm . . . maybe this helps as general reference

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