Atmos. Chem. Phys. Discuss., 13, C13594–C13607, 2014
www.atmos-chem-phys-discuss.net/13/C13594/2014/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Evaluation of IASI derived dust aerosols characteristics over the tropical belt" *by* V. Capelle et al.

V. Capelle et al.

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Received and published: 21 May 2014

Review of paper: Evaluation of IASI derived dust aerosols characteristics over the tropical belt by Capelle et al.

Positives - needed comparisons to demonstrate the capabilities of a new promising aerosol retrieval - use of the right evaluation data (although for CALIPSO the nonsph. extinction should be used) - sensitivity test to examine retrieval limitations (although size was not among them) - nice overall structure of the paper

Concerns - use of monthy coarse gridded matches is limiting (daily matches are way better) - NO evaluation of the AOD bias – due to adjustment to AERONET AOD - correlations are only meaningful, in case of sufficient variability - correlations should

distinguish between spatial and temporal applications - correlating all data over a year confirms foremost seasonality (and not variability) - the arguments for the elimination of outliers is not convincing - retrieval of coarse effective radius is encouraged (could be validated against AERONET inv.data)

@@ Authors to Reviewer : - please see answers to the Editor. - the time period covered in the paper has been extended to June 2013. - minor : IASI sounds from the thermal to the near infrared, not in the “far-IR”.

General comments The paper evaluates retrievals of (coarse size) dust aerosol over lower latitudes via the high spectral resolution far-IR IASI sensor data. This new IASI retrieval method complements common solar reflection aerosol retrievals. Although, this method is only sensitive to larger aerosol sizes, the retrieval offers, aside from data on coarse mode aerosol amount, also (at least over oceans) data on coarse mode aerosol altitude. In this presentation, these retrieved IASI aerosol products are compared to trusted coarse mode AOD reference data of AERONET sun-photometry and to altitude information of the active space-borne lidar sensor of CALIPSO.

The evaluation concept is great, only the offered content disappoints. There is no evaluation of the AOD bias. As I understand it, the evaluated IASI AOD is corrected by multiplying multi-annual ratios of IASI (far-IR) AOD to AERONET(vis) AOD. What is the IASI AOD, if there is no AERONET station to scale to?

Then there are these very coarse scales (monthly and 1.5*1.5deg), which brings up contaminating issue with regional representivity or averaging. I had hoped for daily data, which via more numerous samples would be also more meaningful.

Then there is the use of correlations to demonstrate skill without really looking into the meaning of such correlations. When a satellite product is evaluated, then answers are expected for data coverage and data accuracy, where the accuracy should address bias, spatial and temporal variability. Unless these elements (preferably at smaller scales) are addresses I consider this an incomplete effort. @ - Several aspects of the

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retrieval algorithm: robustness to aerosol model (size distribution, shape, and refractive indices), possible contamination by other aerosol species, radiative transfer model bias removal, or cloud mask including discrimination between clouds and aerosols, etc., were investigated and details may be found in Pierangelo et al., 2004. - Spatial and temporal variability of the IASI-derived products is illustrated on the site-by-site time series shown in the Supplementary Material. More details are now given on the biases (see below and answers to Reviewer 2).

Minor comments tables and figures (I started here, because they need to be self-explanatory) Table 1 The table lists 38 used AERONET sites. I wonder if this table is necessary, as location information and quality information (level 1.5 or level 2.0) could be directly incorporated into the other Tables 2/3/4 @ doing so would also complicate Tables 2 to 4 and degrade the readability of their main content. We would prefer keeping them as they are.

Table 2/3/4 These tables summarize correlation scores of coarse AOD over ocean and land (vs. AERONET) and of 'central' (?) AOD altitude over oceans (vs CALIPSO). If I evaluate I certainly would be interested in correlations. But I also would be interested in bias. Why are average biases not listed? Also correlations have a temporal (time-series) and spatial aspect (distribution). The listed station correlations are apparent temporal correlations (which should be mentioned). In order to summarize, these temporal correlations could be averaged over all stations. Aside from temporal correlations, there are also spatial correlations, which investigate the skill to reproduce spatial patterns. Once you merge all data you mix spatial and temporal aspects, so that the 'all site merged' correlation is not directly comparable to the individual temporal correlations (and it is on average much higher than individual correlations). In addition, the 'all merged correlation' are biased towards the performance at stations with more data-points. Finally a word of caution regarding correlations: Correlations are only meaningful, if there is variability. Thus, some info on the local variability could be nice. @ The bias issue is now extensively addressed. Temporal correlations, together with

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the normalized standard deviation of IASI (representative of the amplitude of the seasonal cycle at each site), are given and discussed throughout the paper. The latter has been added to the results presented in Tables 2-4. Moreover, the time series, given as Supplementary Material, inform on the space (sites) and time (period covered) variability of the IASI results compared to that of the AERONET measurements. As suggested by the Reviewer, and if the Editor recommends it, we will move this material to the main paper.

Figure 1 This is far from perfect, since the 3-letter labels are really difficult to distinguish (even though a separate inset id offered for the Arabian peninsula (maybe the location crossed can be increased to much bigger black dots and possibly the station labels can be removed). It also would be nice to show by different (larger) symbols or colors, which data are used for ocean, for land and for altitude evaluations. @ We tried several other configurations with advantages and drawbacks and finally came to this presentation. Some sites are used both over land and over sea... Not "perfect" perhaps... Figure 2 These are fairly wide size-distributions (but all least all are smaller than the assumed size in the look-up table). I also prefer to use (number) mode radius and std deviation, which are common input variables in MIE simulations ... rather than effective radius and variance. I also wonder why there is only the link to 10um data. IASI has a lot of spectral information, so dust size could be of the retrieval @ The values displayed Figure 2 (now Fig A.3) for the effective radius and the standard deviation of the distribution are taken from the AERONET database for the 38 sites analysed over the IASI period (2007-2013). These values, displayed Fig. A.1, vary from about 0.5 to about 0.8 for the coarse mode. Moreover, it is shown in the Appendix that the impact of the distribution size on the normalized extinction efficiency, and finally on the brightness temperature, is negligible (in agreement with Sokolik et al, JGR, 1998 and Pierangelo, 2005, PhD thesis: see above reference). This is why we kept the OPAC value of 0.8. Regarding the variables we use, the suggestion of the reviewer, more familiar with different, but equivalent variables, won't change the figure. Finally, regarding the link to 10μm data, we agree with the reviewer that IASI has a lot of spectral

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information; this is why, in order to use the whole potential of this instrument, we use in the retrieval channels distributed along the whole infrared spectrum (indicated by vertical black lines on Figs. A2 and A4). The final AOD, expressed at 10μm, corresponds to the different AOD of each channel, expressed at 10μm using the extinction coefficient. Concerning the use of IASI to determine dust size, Fig. A4 of the Appendix shows that, between 9 and 10μm, brightness temperatures are only slightly sensitive to the size of the aerosol (the sensitivity is of second order compared to the sensitivity to AOD; therefore size has only a very small impact on the AOD retrieval, for which all the channels, except a few, are not sensitive at all to the radius (see Peyridieu et al., 2013 for more details on the effective radius retrieval.

Figure 3/5/7 It would be nice, if some basic information on the Taylor diagram could appear in the captions (and not only the text). Say for instance that standard deviation ratios are the radial component and temporal correlation is show on the circular component. I am puzzled why in Table 3 CapeVerde and Dakar, stations affected by significant dust, are doing so poorly?... but it probably has to do with the scales (when starting with the figures, I expected daily matches rather than monthly average matches). I also wonder about lower variability of IASI over land in Figure 5 ... are scales again an explanation? @ - Figure legends completed. - Capo_Verde(11), which appears in Table 2, with a correlation of 0.86 and a normalized standard deviation of 0.85 behaves quite well. The problem of Dakar, appearing both in Table 2 and Table 3, is detailed in section 4.1.2. There is, in particular, a problem with the phase of the seasonal cycle. - In Fig. 5 (now, Fig. 4), the main problem, as said in the text, is undoubtedly that of the refractive index.

Figure 4/6/8 Aah, finally! Bias and difference statistics. Please include details on the boxes and whiskers in the captions. ... after reading later the document more carefully: This is NO\T the bias. The bias is not even investigated! But, it should. @ Bias issue : please see answers to the Editor

Figure 9 Spectral dust absorption features in the far-IR [thermal IR] are important to

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be considered in the IASI retrievals (and it might be nice to indicate agreement or even include data suggested by Sukolik) @ - refractive index impact is detailed in the Appendix. Four refractive index models are considered. We intend to use other refractive index models in the future. - Reference has been made to Sokolik's paper.

Figure 10 This is quite a mess and not really convincing that red (assumptions) are better than blue (assumptions)... other than that there is variability. Do not use lines from station to station (as I automatically thought of a time-series) but rather use lines between red and blue symbols or just only symbols. @ - This is clearly not a time series as the site codes appear on the x-axis. The suggestion with the lines would not really change the appearance of this figure. - Figure caption has been clarified and now reads : "Differences, site by site and total, found between the "MITR" and "Revisited" evaluations (see text) for the AOD (IASI versus AERONET) and for the sites over land (see Table 3). Differences in correlation are shown in red; differences in amplitude (normalized standard deviation) are shown in blue. Positive (resp. negative) values mean better correlation and amplitude closer to 1 (amplitude of the AERONET reference) for "MITR" (resp. "Revisited"). "

Now to the text:

Abstract you "mention normalized standard deviation" ? Better explain what is means so the associated value of 0.96 is better understood (are you saying that the standard deviation is on the order of the mean). If so, it seems unfair since a large portion of it may be related to seasonality and not to local variability. ... later in the text I found out that your normalized std.deviation is, just the ratio between the standard deviation of the test data (IASI) and that of the reference data (AERONET) and then a value close to 1.0 is desired. @ modified; now reads : "...normalized standard deviation (i.e., ratio of the standard deviation of the test data (IASI) to that of the reference data (AERONET)) is of 0.93, close to the desired value of 1."

I also miss in the abstract on what scales the IASI data are evaluated. That has to be in

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the abstract. @ “the overall correlation” replaced by “the overall temporal correlation”

The sentence starting with “To the reasons listed above . . . “ does not make sense to me @ paragraph concerned changed to: “Altitude results over land, essentially over deserts, are not satisfactory for a majority of sites. The smaller sensitivity of IASI to altitude compared to its sensitivity to AOD, added to the difficulties met for the determination of the AOD over land (surface heterogeneities), explain this result. Work is in progress to solve this difficulty.”

When mentioning the importance to climate, there should be also mentioned that IASI data could be very important to constrain IN concentrations in modeling as information on dust (the main ice nuclei) and altitude (distribution) is given. Certainly, if in addition also dust size could be addressed (e.g. 2um reff of 4um reff?) that would be an even better constraint. @ The relationship with ice nuclei is not straightforward because of the mean altitude of the dust coarse mode, rarely exceeding 5 km. It is more the accumulation mode which is concerned. Dust size is also an IASI product (Pierangelo et al., 2005, Peyridieu et al., 2013, section 3.5), out of the scope of the present paper

Introduction What is meant with “particles in the coarse mode are less efficient in their interaction with visible wavelength . . . “ this is very unfortunately phrased, as coarse mode aerosol has the same or even larger AOD in the visible (compared to the far infrared). If a comparison to fine-mode aerosol was meant, then it still depends on the AOD involved for fine-mode and coarse mode . . . please rephrase. @ Rephrased. Now reads : “Visible wavelengths are sensitive to both fine and coarse mode particles when infrared wavelengths are essentially sensitive to the coarse mode. Associating these two spectral domains should help improving our knowledge of the impact of aerosols on climate, its variability and evolution.”

IASI The second step of the method determines the 10um AOD and the AOD central altitude. Does this mean only the far-IR [thermal-IR] spectral data (and dust refractive indices) are only used at 10um? @ Obviously not. They are used at all the wavelengths

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entering the retrieval process (see Peyridieu et al. 2010-2013 for details). See also Figs. A1-A4 of the Appendix, marking the IASI channels used here.

Give some more detail how the coarse mode effective radius is determined . . . as apparently only one (wide) dust distribution is given. @ This has been done in Pierangelo et al., 2005 and in Peyridieu et al., 2013, section 3.5. This was out of the scope of this paper. As already said, the sensitivity to the size is of second order compared to the sensitivity to AOD (see Fig A.4 of Appendix) and so the effective radius used doesn't significantly affect the retrieval (see also Peyridieu et al., 2013).

I am disappointed that only monthly averages are used (I had hoped for daily data matches). This makes the comparison rather general. But when already using monthly average, have you given a thought on comparing the 'retrieved' coarse mode aerosol effective radii to those of the AERONET inversion? @ Many papers, including recent ones, still deal with monthly means and their results prove being helpful for climate variability and evolution studies. Moreover, comparisons with CALIOP are not possible at daily scale. However, work is in progress to analyze IASI results (AOD) at daily scale. One sentence has been added at the end of the paper.

AERONET The temporal mismatch (daytime AERONET and 9.30pm IASI) is a handicap. Also how are the monthly SDA data determined (I only can hope that coarse mode AOD of individual samples is averaged). @ This is less a handicap for monthly means than for daily means. Aeronet SDA data are desarchived from the Aeronet site, heading : " Spectral Deconvolution Algorithm (SDA) Retrievals – Fine Mode AOD, Coarse Mode AOD, and Fine Mode Fraction ". Use is made of the "daily average"; no significant differences seen with the "weighted average".

CALIOP It would have been much better to use from CALIOP data the non-spherical extinction data as they relate directly to dust. @ Indeed, the use of the standard CALIOP (provided by the NASA/CNES teams) dataset is another option. However, we did not consider this option for the reasons mentioned in Tsamalis et al. (2013).

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The most important of them is the uncertainty about the lidar ratio. CALIOP, as an elastic lidar, cannot retrieve the extinction coefficient profile without an assumption about the lidar ratio. The value used in the CALIPSO algorithm is 40 sr. For dust aerosols, the lidar ratio can vary between 30 and 70 sr according to statistical studies, with case studies reporting values between 20 and 100 sr, while even within the Sahara and Middle East, where the majority of aerosols are dust, the lidar ratio varies significantly. Note also, that CALIPSO AOD does not account for the multiple scattering, which is non-negligible in the case of dust aerosols. More details can be found in Tsamalis et al. (2013). Recent studies further confirm our choice, by finding significant AOD differences between CALIOP and other instruments. For example, Ma et al. (2013) used the Level 3 CALIOP monthly mean gridded AOD products (daytime and nighttime) for cloud-free conditions (which is the product suggested by the Reviewer) to compare with MODIS monthly AOD: they report that CALIPSO AOD is significantly lower than MODIS AOD over dust regions (Sahara and northwest China). Similar underestimation has been found by Tsamalis and Chédin (2013) when comparing the CALIOP Level 2 layer product AOD (both for daytime and nighttime) with MODIS Deep Blue and MISR AOD over Sahara and Arabian Peninsula. In order to reduce the bias of CALIOP AOD in case of dust over northern Africa and Europe, Amiridis et al. (2013) proposed the application of a lidar ratio of 58 sr (instead of the present value of 40 sr) to individual Level 2 dust related backscatter products. Over the ocean, AOD comparison of CALIOP with MODIS for the case of dust aerosols (as characterised by CALIOP) shows a relative underestimation of 13% for CALIOP (Kim et al., 2013). Regarding the extinction coefficient at 532 nm, Tesche et al. (2013) report an underestimation of up to 30% for observations over the Capo Verde region (mostly dust aerosols). Finally, the comparison of CALIOP daytime AOD with AERONET observations revealed a median relative difference (underestimation by CALIOP) of 25% (Omar et al., 2013). Another issue is the misclassification of dust layers as polluted dust (e.g. Tesche et al. (2013)) or even as marine aerosol into the marine boundary layer, which modifies the AOD, as the lidar

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ratio of polluted dust or marine aerosols is different from the one of dust aerosols. Note also that for CALIOP Level 3 the Data Product Maturity is beta (http://www-calipso.larc.nasa.gov/resources/calipso_users_guide/data_quality/index.php#lidar), while we are using information from the Vertical Feature Mask of which the Data Product Maturity is Validated Stage 1 (same link as previously). We however agree with the Reviewer that, ideally, one should compare the mean altitude from IASI (given its dependence on the AOD) with an extinction coefficient (or AOD)-weighted altitude from the lidar. This could be the case for the forthcoming mission EarthCARE, where the ATLID lidar has both high-spectral resolution (HSRL) and depolarisation capabilities, which can provide directly the extinction coefficient for dust aerosols (independently of the lidar ratio). Finally, the bias between mean altitude (used here) and mean weighted (by the extintion coefficient) altitude cannot be estimated as the true lidar ratio for every dust layer is unknown.

Added in the text, p. 30147, line 29 : "and the possible misclassification of dust layers as polluted dust or marine inside the marine boundary layer, which in turns affects the assignment of the lidar ratio. These issues, already discussed in Tsamalis et al. (2013), are related to the fact that CALIOP is an elastic lidar, meaning that it needs an assumption about the lidar ratio to retrieve the extinction coefficient. Recent studies further corroborate our choice, by finding significant AOD differences between CALIOP and other instruments (Amiridis et al., 2013; Ma et al., 2013; Omar et al., 2013; Tesche et al., 2013). "

Method

I do not get the 1.5*1,5 grid . . . I thought it is 1*1? @ From a review of papers dealing with remote sensing of aerosols, the 1.5°x1.5° resolution cannot be called "very coarse". Here, the aim is to somewhat increase the signal to noise ratio with the risk, the Reviewer is right, to bring some contamination, potentially masking the real performance of the method. One has, however, to keep in mind the fact that AERONET data are obtained daytime, when IASI data are obtained nighttime (at present). Research

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advancing step by step, we are already starting working on the daily issue, at a higher spatial resolution. It must also be pointed out that monthly results at such a space resolution (current IASI aerosol products resolution is 1°x1°) are still considered as very useful for climate research (study of climate variability and evolution). These data need being evaluated. See also answer to the Editor.

What defines a valid month value for each data-set (give the minimum # of samples) ? @ Valid month : A valid month has an AOD>0.02 and an altitude>1.0km; these values have been added. The number of items, as well as the quality of the AERONET observations are addressed in 2.2.

I am confused about the ratio between AERONET coarse mode AOD and IASI AOD. The plan here (as I understand) is to evaluate the IASI skill to determine coarse AOD, size from spectral information and altitude. Now if you prescribe the local conversion factor this does NOT test the skill of IASI to get reliable coarse mode AOD data. And what will you do in cases that there is not matching AERONET sample? Then also all these box and whisker plots address monthly variability but NOT bias. I hope this is not true. If so, please do NOT prescribe a ratio based on AERONET, as your LUT already uses (based on size assumption and refractive indices) such a ratio. . .. and the paper should evaluate the retrieval skill (without cheating). In any case you should your LUT make a function of size (assuming one size or size distribution will not work, since especially over the Sahara effective dust sizes are often larger) and there is sufficient spectral info in the IASI sample to address size. @ - That part of your sentence is not clear to us : ". . .is to evaluate the IASI skill to determine coarse AOD, size from spectral information and altitude" ; we here determine AOD and altitude from the IASI spectral observations. - bias issue : please see also answers to the Editor. - the important issues raised here by the Reviewer are now detailed in the new Appendix A, in section 3, etc. - size : answer already given. - A. Chedin and co-Authors to Reviewer n°1:We cannot accept the word "cheating" .

With respect to IR/vis AOD ratios larger than 1.0: This is possible, if sizes are larger

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(ca 5um radius) and narrower in the width (the assumed 2.2 std deviation of the LUT is way too large and will smooth spectral detail). To make proper use of IASI spectral information you should use narrower size distributions variances between 0.3 and 0.5. @ As already said, IASI-retrieved AOD is not significantly impacted by the size distribution parameters, whereas the IR/Vis ratio is impacted (see Fig. A3). From this figure, the large ratio found at Tenerife might indeed be interpreted as being due to a large effective radius or a small width of the size distribution, independently from the AOD we have estimated.

Why are outliers removed? Is this not cheating? Although you offer potential reasons for outliers, how do you know that these reasons apply? If you cannot proof it you have to keep the outliers. @ - We won't comment the new "is it not cheating"... - As explained in this paragraph, this procedure allows eliminating cases which would otherwise mask the real performance of the evaluation. This is common practice. Obviously, such outliers (7 out of 100) can "contaminate" further use of the data (although methods actually exist to detect them), as it is the case for all retrieval processes... Moreover, statistics including the "outliers" are given throughout the text. One sentence added : " This procedure allows eliminating cases which would otherwise mask the real performance of the evaluation."

Results (reminder: Just add the explanation of Taylor and Box plots in the figure caption) @ What does the Reviewer recommend ?

The box plots show difference between "AERONET/IASI average scaled" IASI AOD and AERONET AOD. By leaving the " . . ." aspect out, there may be misunterpretations. @ added to legends of Figs. 3 and 5 : ". . .and AERONET 500 nm coarse mode AOD (scaled by the site-ratio as explained in Section 3)"

The mixing should not be a problem . . . if the SDA method work. Of course if other particles cling to coarse aerosol the refractive indices could be affected but given the uncertain impact from changing refractive indices, I am not sure if the mixing has a big

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impact on the retrieval. I agree that the temporal mismatch near sources could be a problem on a daily basis - but not so much on a monthly basis unless there are regular repeating wind-strength cycles. @ We have shown that changing the refractive index may have an important impact. OK for the other comments.

In the sensitivity studies changes in the assumed refractive indices are one aspect and size assumptions (which are not investigated) are another. I am not so sure we learn so much from a different refractive index if the size-assumption is incorrect. @ As said above, the size assumption is not a relevant problem in the infrared. The new Appendix details the sensitivity of brightness temperature to the size assumption.

If you think that time-series are important for a subchapter you should at least present a figure (I do not like references to supplements) either at least a figure or remove the text. @ If the Editor recommends it, we will move this material to the main paper.

Discussion The bias issue is side-stepped . . . at least problems with the multi-annual IR/vis AOD ratio are acknowledged. @ Bias issue already discussed.

One problem may be the refractive index assumption . . . but a bigger problem is the fixed size and an unrealistic wide size-distribution. Any retrieval improvement should make size a flexible parameter. @ Answer already given.

If you use daily data (despite the exact temporal mismatch) . . . there will be many more matches and the evaluation will be more meaningful. @ Answer already given

The last paragraph mentioned “the overall agreement for AOD”. This is an overstatement, as the paper only shows a reasonable temporal correlation. Spatial correlation and bias skill have not been demonstrated. @ OK for the correlations (temporal); an overall value of 0.93 (38 sites, 6 years) is perhaps better than “reasonable”. . . In addition, we have shown the time series (IASI vs. AERONET) and their spatial variability from one site to another. The bias issue is now discussed in detail. The presence of important biases seems incompatible with the correlation results. Altitude biases are

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also given.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 30143, 2013.

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