Atmos. Meas. Tech. Discuss., 8, C524–C530, 2015
www.atmos-meas-tech-discuss.net/8/C524/2015/

Atmospheric Measurement Techniques Discussions

Interactive comment on "A novel retrieval of daytime atmospheric dust and volcanic ash heights through a synergy of AIRS infrared radiances and MODIS L2 optical depths" *by* S. DeSouza-Machado et al.

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Received and published: 3 April 2015

- 1. AIRS Dust Flag

  The dust flag used is described in the referenced JGR 2010 paper; we now explicitly state this is the one used in sub-setting pixels from AIRS granules. We do add the caveat that the flag was developed for dust over tropical oceans, with the liens that is does not detect low optical depths or some species of dust, and can

  produce false positives over land.

- 2. Cloud Effects

  We have added a few sentences in the Introduction and Retrieval Algorithm sections, stating that cloud effects do need to be taken into account. In the retrieval, a "surface temperature" adjustment was made using channels in the 1231 cm-1 region were used, and is now explicitly stated. This could be problematic for the case when thick high cloud is present, and we plan to have a warning flag if the adjustment is larger than 10 K, as the present algorithm only simultaneously shifts the profile by scaling the δ(surface temp) from 500 mb to the surface.

- 3. Why are AIRS L2 products not used?

  Our assessment, based on looking at radiative closure and AIRS L2 products as a function of AOD, is that dust makes it through the cloud clearing process and adversely affects the retrieved products. In addition the quality flags at the surface and lower troposphere show there are problems in those geophysical products. We now state this in the manuscript.

- 4. the 1:4 factor is not motivated, and may be contradicting other results

  The $f_0 = 4$ factor came directly from the DeSouza-Machado et al (2010) JGR paper (see Section 6.3, second paragraph on pg 9 of that paper). That paper explained the use of MODIS total optical depth (fine+coarse) product, as the MODIS algorithm sometimes does not correctly separate out the fine/coarse modes. That same factor of 4 also worked for some other dust storms since analyzed, and therefore was used to produce the results presented in the AMTD paper, which were compared against a much larger sample of CALIOP heights

with very reasonable results.

In view of the referee's concerns we did investigate this factor. The Capelle et al (2014) paper analysed data over a large region/time span and suggests a lower factor, between 1-2, obtained by comparing against the AERONET coarse mode OD. As AERONET uses non-spherical particle assumptions in its retrieval, it should be more accurate than the MODIS product.

A year's worth (2007) of MODIS retrieved fine fraction co-located to the AIRS detected dust was gathered, and divided into geographic regions (over ocean). The resulting means and standard deviations in the regions were (a) Atlantic 0.33 +/- 0.13 (b) Pacific 0.35 +/- 0.16 (c) Mediterranean 0.36 +/- 0.13, giving a coarse mode fraction of about 2/3.

We then re-ran the whole data set using factors of 1.5,2,3,4 in the retrievals. The results were noticeably better for the larger values of f_0. Multiplying these values by the coarse mode fraction from the previous paragraph, would mean f_0 = 3 would give a IR:coarse VIS ratio of 2, while a value of 4 would give a coarse mode IR:coarse VIS ratio of 2.66

In light of all the above, our factor of 4 (used with respect to TOTAL optical depth) is plausible, compared to the factor of 1-2 using coarse mode ODs. We maintain using the original value of 4 (over a lower value of f_0 = 3) since our analysis show improved results with the original factor. We have added a subsection detailing the above, and the comment that "the factor of f_0 = 4 can be further optimized in the future"

- 5. Overall Presentation of the results; are they unsatisfactory? Provide plots for

one day example of the retrieval, channel selection

Many spot checks were made comparing our results against CALIOP heights, before writing up the method. Tables 1 and 2 together with the figures in the original document served to show that the methodology and results were of interest to the scientific community, even though they were averaged over geographical regions. An important reason why monthly averaged results were shown, was that as stated in the original paper, the algorithm uses the "height closest to where the MODIS/AIRS OD ratio is 4." This meant that while the retrieved AIRS ODs can be fitted to a distribution, the retrieved heights for both the AIRS/MODIS synergy and χ^2 method were restricted to a discrete set.

In view of the referee's comment, we modified the algorithm so that even though the looping is still done on the original discrete set z_m, the resulting $AIRSOD(z_m)$ were interpolated onto a finer grid so that a crossing point between this curve and the MODIS OD could be found, rather than the nearest height at which $AIRS(z_{optimum})/MODIS$ = 1/4. The implies the AIRS/MODIS synergy heights are now a continuous distribution (though the χ^2 heights remain as a discrete set). This has allowed us to add on a subsection containing an in-depth discussion and 2d histograms of retrieved AIRS vs MODIS ODs, and retrieved AIRS heights vs CALIOP heights (both for the AIRS/MODIS synergy and AIRS χ^2) in pixel-by-pixel comparisons.

The referee requested we take a random day and show results for all geographic regions. We point out that even though AIRS, MODIS and CALIOP almost simultaneously follow the same orbits, it is difficult to take any random day and produce maps showing results over all geographic regions. This is due to a combination of limitations, which roughly in order of importance include (a) the

current AIRS dust flag does not trigger for low optical depths (b) compared to the AIRS swath, the CALIOP beam is narrow, (c) the CALIOP track is often along a region of MODIS sun glint and (d) seasonality of dust storms in different regions. Instead of a random day, we chose to present the detailed results in the form of plots and tables for the Atlantic region; to minimize the length of the paper, an appendix has summary tables for the other regions.

The contents of Tables 1 and 2 of the original document (correlations and means of optical depths and heights) have thus been supplanted by the above material, and they have been removed from the revised manuscript. As the new material has lengthened the document, we have also chosen to remove Figure 12 of the original document (which shows the NOAA HySplit trajectories), and the paragraph pertaining to it.

We have added an appendix which lists the channels used in the retrievals.

- 6. p445 lines 4-8 : Please re-formulate to lay out two retrieval algorithms are presented.

Agreed, we have edited the sentences.

- 7. pg 448 line 3 "though less sensitive than the above"

Agreed, this was also pointed out by Reviewer 3, and we have clarified the statement.

- 8. pg 448 line 9 "CO2 slicing cannot be used for dust retrievals?"

CO2 slicing for clouds is based on spectral bands where CO2 is the dominant and known clear sky atmospheric constituent absorber and clouds/ice have strong

extinction effects. For an analogous dust height retrieval, the spectral region with dominant dust extinction would be the 10 micron band. Radiative transfer calculations in the 10 micron region also require knowledge of the surface and T(z) profile, O3(z) profile (the main constituent absorber), and to some extent H2O. Unless the dust/ash is very optically thick, uncertainty in the O3 amount above the dust/ash will not enable an accurate determination of the dust layer height. This has been added to the manuscript.

- 9. pg 449 line 4-8 : unclear; please reformulate

We have rephrased these sentences

- 9. pg 449 AIRS overpass time

This was already mentioned when discussing the A-Train. By moving all instrument descriptions as requested into a single section, this should now be easier to find.

- 10. Pg 453, Line 20 : other factors impacting accuracy of the retrieval

Agreed, we have added these

- 11. Pg 458, Line 8 : Typo in sentence

Thanks for pointing this out, we have deleted "is the"

- 12. Pg 459, Line 21 : Extra brackets

Thanks for pointing this out, we have deleted them

- 13. Pg 460 lat/lon coordinates

  We have written a couple of sentences to clarify these are the areas that the dust flag triggered, such as NW and W. African coasts, Mediterranean, Arabian Sea, and Pacific; in addition to the Sahara

- 14. Put all instrument descriptions together

  All instrument descriptions are now together in Section 2.

Interactive comment on Atmos. Meas. Tech. Discuss., 8, 443, 2015.