# Response to latest comments by the authors of **Evaluation of aerosol optical depths and clear-sky radiative fluxes of the CERES Edition 4.1 SYN1deg data product**

## *General comments*

My comments are based on the recent responses by the authors, I received by e-mail. The authors simulated in sensitivity studies the dust treatment (for direct comparisons to my offered simulations), to demonstrate consistency and importance, which is appreciated. Still, it is apparent that in the described MATCH model, dust size underestimates (despite dust RFimag overestimates) may cause likely biases and at least offer a possible answer to the 'unresolved' bias issues. Aside from the dust-issue though, there are still larger differences between MATCH and MERRA which at least should receive some attention – as both models assimilated MODIS AOD data, which would imply a better agreement than demonstrated. So make sure that critical deficiencies and differences are well explained.
As the MATCH data output is used in the CERES (surface) flux products, it is important that context on assumptions - also via this paper - to the applied AOD values are revealed, independent of their accuracy. Thus, I do want to not to hold up a publication any further.

## *Specific responses*

*Based on your comments below regarding the dependence of irradiance on particle size, specifically Table 6 in the paper, we have found that one SW number was incorrect. Once the correct number was in place, we find that we do not need to re-evaluate our calculations as they agree with the values provided in your review. While, at the same time we also agree that the SSA in the OPAC tables being used for dust particles likely underestimate SW absorption.*

Good to hear that the corrected mid-visible SSA for dust are now more consistent with my simulations (although more to the fact that underestimates in size is compensated by overestimates in dust imaginary part) – see below. As severe underestimates in dust size remain, I would worry about mismatches for longwave radiation (no size → no LW extinction)

*'The difference is largely due to the differing methods of assimilating the MODIS AOD data product and the use of quality flags in our assimilation.'*

*We believe it (the unusual land-sea contrast) is the MATCH model (and so 'base-line model assimilation') that is one of the primary sources of the differences. We state as much in lines 234-235.*

Are there arguments why MATCH or why MERRA assimilations should be trusted more … as the resulting AOD maps are so different? Does it simply mean that the influence of the baseline model (e.g. CAMS vs GOCART) is much stronger than the impact of the AOD data assimilations? That would be an important 'help/issue' to any manuscript reader.

It is a bit puzzling to me that you say that the ‘undesired’ land-sea contrast is likely associated with the MATCH model – as models are not expected to show these inconsistencies. It would be nice to get some more insights as to the reasons .. why?.

*MATCH optical thicknesses over desert sites for clear- and all-sky conditions are larger (Tables 3 and 4). Computed downward shortwave from North Africa groups is larger than observed downward shortwave irradiance at the surface. As the reviewer suggested, it appears that we underestimate shortwave absorption, if particle size is larger. Here are the single scattering albedos as a function of dust particle size with OPAC refractive index. These single scattering albedos are low compared with those provided by the reviewer.*
*Single scattering albedo of dust particles with OPAC refractive index*
*Particle size 1.9 (2.15) 0.78 (2.0) 0.39 (2.0)*

Is this particle size and diameter? Then this refers to reff of 0.95, 0.39 and 0.19um? This is way too small for dust.

*546 nm 6.67931E-01 8.00413E-01 8.78470E-01*
*642 nm 7.15135E-01 8.46123E-01 9.11902E-01*
*842 nm 7.63865E-01 8.85041E-01 9.37848E-01*
*1226 nm 7.84489E-01 9.02001E-01 9.47219E-01*

Given the listed spectral SSA at these small reff sizes in MATCH I conclude from comparisons to my data that the assumed (and likely outdated) imaginary part in MATCH is much larger than my mid-visible value of 0.0011. So there is a compensating effect for dust SSA but not for dust size. Speaking of size, I found in an older paper-version (sorry I did not have access to the current version of the paper) this table, where the use of larger dust sizes was reported (see below). This needs some clarification.

Table 2. Mapping of MATCH aerosol types into Radiative Transfer code.

| MATCH Constituent | Langley Fu & Liou Constituent | Langley Fu & Liou Spectral Properties |
|---|---|---|
| Sea Salt | Maritime | d’Almeida 1991 |
| Hydrophobic Organic Carbon | Insoluble | OPAC |
| Hydrophilic Black Carbon | Soot | OPAC |
| Hydrophobic Black Carbon | | |
| Hydrophilic Organic Carbon | Water Soluble (WASO) | OPAC |
| Tropospheric Sulfate | | |
| Volcanic | Suspended Organic (SUSO) | OPAC |
| Stratospheric Sulfate | | |
| Dust < 1.0μm | “Small” Dust | Sinyuk et al. (2003) |
| Dust 1.0 -2.5μm | “Large” Dust | Sinyuk et al. (2003) |
| Dust 2.5-5.0 μm | | |
| Dust 5.0-10.0 μm | | |

*We believe that the dust size the reviewer mentioned in his comment on line 174 is too large. But we get similar single scattering albedos with a smaller size using OPAC refractive indices.*

*Figure 1 shows the values currently in the radiative transfer model and so represent the calculations in the SYN1deg data product. Changing the values is not currently an option for the operational SYN1deg product.*

The given dust sizes in my 174 comment were only given to demonstrate the size-effect on SSA for mineral dust. Typical dust sizes have a reff near 1.5um (so in that context the authors are correct with their 'too large' statement). However in regions around dust sources, mineral dust aerosol sizes will be larger (at least reff=3 and up to reff=6). I am still worried about the smaller size options in MATCH. If and where (the authors should know) these are applied, dust absorption is likely underestimated. Maybe this can help in their bias assessments.

*We have changed the sentence to suggest the error may be due to the choice of dust particle size and distributions.*

Thanks, such a statement is much more satisfying.

*The log density plot does show the vast majority of AODs are less than ~0.6. And though the fit line is 'pulled down' somewhat by the larger AODs we feel a log/log plot on top of the log density would not significantly change the results presented. It might bring the fit line a little closer to the 1-1 line, but the point that both MERRA2 and MATCH underestimate AOD relative to MODIS will not change. It is also re-iterated in the statistics below the plots.*

The biases vary with AOD ranges (usually satellite remote sensing suggest larger (and likely overestimates) AOD at low AOD values, while AOD maxima are often missed) so possibly a separate linear plot for just the 0-0.3 AOD range could be an useful extra.

*First. we'd like to point out that there was in fact an error in Table 6. The value for Downward SW irradiance for particle size 2.0µm should have been 1038Wm-2, not 1028Wm-2. This has been corrected in the paper, line 489. This then brings our table values into line with the values presented above by the reviewer. Specifically, he records, for a fourfold increase in particle size, a decrease in DSI from 983Wm-2 to 968Wm-2 (~16Wm-2 or -1.5%). With the correct value in Table 6, a fourfold increase in particle size (2.0µm to 8µm) the DSI in our calculations decreases from 1038Wm-2 to 1020Wm-2 (~18Wm-2 or 1.7%). If we change our cos(SZA) to 0.95 (as the reviewer used) the DSI values at 2.0µm and 8µm are 977Wm-2 and 960Wm-2. So again, a similar decrease of ~17Wm-2 but the same percentage of 1.7%*

Thanks for checking/confirming

*The longwave numbers are correct in Table 6. To comment on the reviewer's statement that 'LW dust impact on downward fluxes depends strongly on the assumed dust vertical distribution as much as on size', in our offline radiative transfer model we increased the scale height of 1.5km to 5.0km for the same inputs as shown in Table 6. This resulted in DLI values at 0.5µm , 2.0µm and 8.0µm particle sizes of 351Wm-2, 357Wm-2 and 359Wm-2 respectively. Thus, increasing the scale height of the dust particles did not change the DLI by more than 1%, less than the changes due to particle size. This of course kept the particle size the same throughout the column which does not account for the fact that smaller dust particles are more likely to be lofted higher in the atmosphere.*

Thanks for the detailed answer, also working with ‘my’ relatively large sizes for dust. Unfortunately, these larger dust sizes are not considered in MATCH (correct me if I am wrong) so my concern was mainly that with max allowed dust diameters of 1.9um there would be no dust associated longwave effects as with larger dust sizes of the sensitivity simulations – mainly to TOA fluxes (where altitude placement matters) but also to longwave surface fluxes (where altitude placement is less of an issues – but opposite to TOA as: the lower → the stronger).

*we imply that more clouds indicate more AOD in the MODIS AOD retrieval process as reported in the Varnai et al, 2017 reference.*

You are right, that in case of more (near-by) clouds MODIS retrievals tends to overestimate AOD but the reasons are less apparent. Most overestimates (over cloudy mid-lat. oceans) though are linked to fine-mode AOD so things are more complicated than simple cloud contamination. In case of modeling, things are less clear, as removal processes via clouds may dominate aerosol swelling effects.

*At this point in the processing of the MATCH model and its subsequent use in the SYN1deg radiative transfer calculations, we cannot ‘redo our large dust SSA calculations’. What we have done, and at this reviewer’s suggestion is try to show, in the paper, potential error due to the constraints we currently have on our dust models in the radiative transfer code (Table 6) and the MATCH model’s ability to define large and small dust, Figures 15, 16 and related discussion.*

I understand that for the current MATCH version the SSA cannot be redone. So if potential MATCH issues it stated that should suffice for now.