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Atmospheric Measurement Techniques Discussions

Interactive comment on "Retrieval of effective aerosol diameter from satellite observations" *by* Humaid Al Badi et al.

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We thank Reviewer#2 for his comments. This reply is structured by introducing sections of the comments (in Italics) followed by a response. The page and line numbers of the updated version of the paper are used in the responses. The amended manuscript is attached in the supplement PDF file.

Section 1: "The correlation between T and dust aerosols is rather complex and linked to many parameters. It is mainly caused by Aerosols Optical Depth(AOD), dust particle size and shape and the emissivity which in turn linked to dust chemical composition (e.g. Brindley et al. 2012; Kluser et al. 2011)." The satellite measurements are also sensitive to the surface temperature, surface emissivity, atmospheric water

vapor and temperature, and viewing angle. For optically thin dust clouds, the non-dust cloud property components are especially relevant. Thus, I do not agree with the statement as written.

We agree with the reviewer that there are many other variables which affect brightness temperature. The statement was intended to highlight the complexity of correlation between T and the dust optical properties. It did not intend to refer to all the variables in the radiation transfer equation. To ensure that we are writing about dust properties only, we started the sentence with "The correlation between T and dust aerosols". The statement is trying to convey that even if the other variables are known, the problem of retrieving dust particle size through analytical approach is still complex because a dust layer alone has many variables which might affect the T.

Action: More detail has been added to the statement to ensure clarity of the paper - Page 3, line 4 to 15.

Section 2: The authors should acknowledge that dust particles are not spherical. While I believe that the assumption of spherical particles is a secondary issue, motivation for treating dust particles as spheres should be provided.

The authors acknowledge that the variation of dust particle shape and chemical composition leads to a variation of the refractive index with a subsequent contribution to the total error. However, estimation of the error from non-sphericity and variation in chemical composition is a complex task and out the scope of this study. This is partly because it is still difficult to implement the available methods to quantify the effect of non-sphericity in estimating the extinction coefficient developed by other researchers, e.g.(Cheng et al. 2010; Dubovik et al. 2002; Dubovik et al. 2002b; Wang et al. 2003). The chemical composition also has an effect on optical properties of dust aerosols. Different dust sources have different dust composition. As non-sphericity do, the chemical composition affects the refractive index of dust. Klüser et al.(2015, 2016) give a detailed analysis on the effect of non-sphericity and chemical composition on spectral bands in the thermal infrared region. At this stage, the extent of the effect of the non-sphericity and chemical composition is not known when taking the brightness temperature difference between two bands. However, it is still crucial to develop localized accuracy assessment of the algorithm to compensate the difference in the dust particle morphology and composition.

Action: This clarification has been added in Section 4.3 (Discussion of Results), Page18.

It is also not clear as to what kind of size distribution was used in the Mie calculations. If the calculations were done for a single particle then the results are not at all representative of the particle size distributions present in nature.

MiePlot software (Laven, 2016) gives a choice to calculate a Mie solution for a range of particle size distributions. Here the particle sizes are assumed to be lognormally distributed in the range of [0.02 to 60 μm] although it is acknowledged that real distributions could be different. The selection of this range is based on the Ryder et al. (2013a, 2013b) report of volume distributions peaks between [10 to 60] m in fresh, heavy dust events which is the focus of interest for this calculation.

Action: This clarification has been added in section 2, Page4.

Also, the Mie calculations are a function of wavelength. Did the calculations take into account the SEVIRI spectral response functions?

Yes, it has done separately for the 8.7, 10.8 and 12.0 μm as explained in Page 3 Line 25. The empirical formula is built for SEVIRI, hence, we believe the numerical constants in the formula will probably change if another instrument is used.

Section 3: The proportionality arguments do not make physical sense. The extinction efficiency is solely a function of the microphysical properties of the dust cloud, and is intrinsically independent of the incident radiation. In addition, the measured brightness temperature and incident radiation have a complex, non-linear, relationship. Further, the 8.7-12 um BTD is a complicated function of many variables and is not simply proportional to the 8.7 um surface emissivity. As such, the algorithm theoretical basis seems to be badly flawed, which is a primary reason I cannot recommend this paper for publication at this time. The authors need to provide a much more convincing argument for the theoretical basis. The generation of the various empirical relationships is also poorly explained. The term "reemitted" is used. I recommend not using this term as matter emits radiation because it has a temperature. Once a photon is absorbed it should be considered dead and gone. Even though the algorithm is restricted to pixels that meet certain BTD requirements thought to be related to optical depth the background atmosphere and surface and viewing angle will still influence the retrieval to varying degrees. The authors should include a sensitivity analysis that justifies their assumptions, as most modern retrieval methods do not make such assumptions.

There is a typing mistake in the referenced section. Instead of $Q_{ext}\ \alpha\ \frac{1}{I_0}$, it should be $Q_{ext}\ \alpha\ (1-\frac{I_r}{I_0})\ \ (from\ Q_{ext}=\frac{P_{removed}}{I_0})$ where (I_r) is the radiance received by satellite radiometer. The pretext in the introduction and the context that follows the relationships fits this intention. However, the Authors agree that there is over simplification in the analogy of the radiative transfer in *page 4* because of using Rayleigh-Jeans law which is not appropriate in thermal infrared part of the spectrum.

The authors acknowledge the complexity of the retrieving effective dust particle size using an analytical approach. Apart from the recent improvement, many studies tackled this problem through theoretical analysis but had limited success in filling the gap between the observed and the modeled particle size has been achieved to date. The reason, as the reviewer points out, is the high number of dependent variables that link the remotely sensed radiance and particle size in the radiative transfer theory. The high uncertainty in the approximation of variables such as the chemical composition and particle shape, might be one reason to limit the advance in improving the accuracy of retrievals. The results of previous particle size models seem to inherit the noise introduced by the vague estimation of the many dependent variables. In a single thermal SEVIRI band, the effect of dust diameter is potentially "diluted" and difficult to see while the case turn out to be different in Brightness Temperature Difference of 8.7 and 12.0μm (ΔT_{8-12}). This study approach aim to avoid the inherited noise of many dependent variables by exploiting the strong and dominate exponential effect of the particle size on the value of ΔT_{8-12}. Here we try to present the empirical evidence of this relation and then use it to build a formula based mainly on empirical data and a simplified conceptual model.

Action: To make the thesis of the paper clearer, Section 3 has been rewritten to include more details explaining the empirical evidence of the dominant relation between ΔT_{8-12} and effective diameter. More detailed description of the effect of surface emissivity, water vapour, and dust has been also included in section 3. There are also more details for the theoretical basis in section 2. In section 4.3(Discussion of Results) more details discussion on the limitation of the model has been presented.
The word reemitted has been changed.