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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.

Anonymous Referee #3

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This paper uses Mie theory in an attempt to relate aerosol (specifically mineral dust aerosol) size to brightness temperature differences (BTDs) in the thermal infrared measured by the Spinning Enhanced Visible and InfraRed Imager (SEVIRI). The authors use aircraft observations from the Fennec campaign to create an empirical relationship between one of the BTDs and effective dust particle size before comparing other cases from Fennec with values retrieved using their empirical model.

Overall, while I think the aim is laudable I find the approach wholly unconvincing, supported as it is by incomplete physics.

In my opinion there are a number of serious weaknesses described below:

(i) The radiative transfer theory used here is far too simplistic. In reality, in the thermal infrared, one needs to consider both extinction (scattering and absorption) by, and

emission from, the dust layer. Moreover, one has to consider emission from the surface and the underlying (and possibly overlying) atmosphere dependent on the dust height (atmospheric temperature structure) and the wavelength considered if one is to correctly interpret the satellite signal.

(ii) There seems to be no appreciation of the Beer-Lambert law, or alternatively the differential nature of extinction, as radiation passes through a medium. Just considering absorption and removal by scattering by the dust layer alone would lead to an exponential dependence of the final 'intensity' on optical depth, which is itself a function of the extinction cross section. Add in emission, plus scattering into the upward direction and you will obtain the full radiative transfer equation (usually expressed in radiance although conversion to irradiance is possible if done properly).

(iii) The various relationships given near the start of section 3 are hence not correct. In fact, even if the earlier assumptions were ok I can't see how they would logically follow. Why should the extinction efficiency be inversely proportional to the radiation incident on the dust layer? The former is an intrinsic property of the dust and is only dependent on the size distribution, shape of particles and composition. Similarly, brightness temperature is not directly proportional to the radiation incident on the dust. It is not even directly proportional to the intensity (as defined here) on the satellite radiometer but rather results from a non-linear conversion of the incident radiance using the Planck function.

(iv) As noted above, aerosol optical properties are related to composition, shape and size distribution. The use of Mie theory as given implicitly assumes that the particles are spherical which is rather unlikely for dust. Moreover, the authors simply use one set of refractive indices yet compare a number of different cases, including African and Arabian dust events. One might anticipate significantly different compositions dependent on source. While the assumption of sphericity is likely to be less severe in the IR than the visible, at the very least some sort of sensitivity analysis should be performed to assess the impact of uncertainty in the dust composition on the resulting BTDs.

(v) As written, it is difficult to see whether the authors have any concept of the effect of a size distribution. Their Mie calculations appear to have been carried out for single particles (although I am not sure of this as the 'ringing' that one might expect to see in this case is absent). In reality, these responses will be weighted by the fraction of particles within each size bin, which will vary from dust event to dust event (and even during an individual dust event). Hence, when looking at real signals, the shapes in figure 1 will effectively be distorted differently for different distributions of particles such that fitting one empirical model is unlikely to be representative.

(vi) Similarly, have the authors taken the spectral width of the SEVIRI channels into account? It is not clear from what has been written. Since the filters are quite wide they will also affect the size of the signal seen and its variability. The viewing angle of the satellite will also affect the signals seen due to differential absorption through the atmosphere.

(vii) In the derivation of their model the authors appear to make the assumption that the dust plume emissivity is the same as the surface emissivity (at least this is how it reads to this reviewer). This is not valid as, even if the composition is the same, the lofted particles are likely to be smaller and less densely packed than those at the surface.

(viii) It is totally unclear where the 'measurements' at 15 micron used to fit the model have come from. In any case, using two clustered points to perform a curve fit such as that shown in figure 7 is, in my opinion, very bad science. I could fit any line I wanted through those points.

(ix) Although uncertainties are given in table 1 it is unclear exactly how these have been derived. Are these propagated correctly through the model (e.g. do the authors consider the effects of uncertainties in their fit, let alone those in surface emissivity, composition etc.)?

In summary it should be noted that this reviewer is unconvinced that, even using the correct radiative transfer theory, and employing the simplifying assumptions that dust

particles are spheres and have the same composition everywhere, there is enough independent information in a single BTD to extract size information. To do this I would suggest that at the very least, dust optical depth and height need to be known, and even then one would still have to account for the impact of confounding influences such as variable surface temperature, surface emissivity and water vapour content. It may be that there are 'regimes' of behaviour (e.g. dust plumes above a certain optical thickness) where size information can be extracted but I suggest the authors perform a much more comprehensive suite of (correct) radiative transfer calculations (explicitly simulating SEVIRI BTDs, including the relevant instrument characteristics) to look at whether what they are attempting to do is actually feasible. If they believe it is then they also need to come up with a much more convincing strategy for validating their results, including a traceable uncertainty analysis.

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