

The following are responses to the comments from Referee #1. The responses have been highlighted in light blue for clarity. Please note that all referenced pages and line numbers pertain to those found in the submitted manuscript dated 14 May 2010.

The paper shows the variation of extinction in dependence on particle size, shape, and composition. It gives valuable insight into a spectral region where little information on optical properties of dust is available. The spectral shifts in the IR window for non-spherical particles are of particular interest. This shift seems to increase extinction due to the larger geometric diameter of the particles.

The usefulness of the results is limited as mixtures and coating have not been treated in this paper. The OPAC mixture of 10% hematite is almost never used by modelers. Modeling usually uses 2% hematite. The authors should address this issue in more detail with modeling results.

a. The main purpose of this paper is to thoroughly examine MEE and the component MSE and MAE of pure dust minerals excluding coatings or aggregates by other aerosols (e.g., soot) and complex mixtures (please refer to points 1 and 3 on page 5 of manuscript). We do this in order to better quantify and bound the extinctive properties of uncontaminated dust aerosol and to improve our understanding of single mineral properties over this spectral region. Although we believe this is a necessary first step before undertaking more complicated mixtures (please see page 9, lines 212-218) and coatings, some examples (see below) are being added to the manuscript to address these points.

Per the recommendation of referee #1 and to further illustrate the utility of this work, an example of a more complex dust mixture and one which contains soot are being added to the manuscript including (a) the MEE for a mixture of dust minerals representative of those identified during the SAMUM 2006 field study (Kandler et al. 2008) for high and low dust loading conditions and (b) the MEE for a dust-soot mixture using the OPAC database. A more thorough and detailed investigation of dust coatings, aggregates, and mixtures will be formally addressed in an upcoming research study.

b. Additionally, a 2% hematite mixture [e.g., Lafon et al. (2006) and Formenti et al. (2008)] is being added.

1. Title: Does “terrestrial atmosphere” mean “the Earth’s atmosphere” or “the atmosphere observed at terrestrial wavelengths”? Please clarify.

Here “terrestrial atmosphere” is in reference to the Earth’s atmosphere. For clarity, “terrestrial atmosphere” has been replaced by “Earth’s atmosphere” in the manuscript title.

2. The strict definition of “aerosol” includes the suspension medium, i.e., air. The authors certainly have in mind only the particulate component. I suggest that they specify the meaning of aerosols at the beginning of their text.

As the referee points out, aerosol in the current discussion only refers to the particulate component. To be more accurate in the strict sense of the definition, line 87 will be updated to read, “Note, although the strict definition of aerosol includes the suspension medium, i.e., air, this study only refers to the particulate component”.

3. Page 17220: The authors may want to comment a bit more of the choice of the OPAC dust model in their simulations. How realistic are the simulations in view of the finding during, e.g. SAMUM 2006.

The following text has been added to address the choice of the OPAC dust model in the simulations: “The former parameterization consists of a mixture of quartz and clay minerals and represents mobilized dust from source regions like the Saharan or Gobi deserts, where many field measurements have been made (e.g., AMMA/NAMMA – Redelsperger et al 2006/Zipser et al. 2009 and ACE-ASIA – Arimoto et al. 2006).”

Using the OPAC dust model is reasonable in light of the findings during SAMUM 2006, since quartz and clay minerals (among others noted in the study) were identified using various methods (i.e., RIR and FULLPAT – Kandler et al 2008).

4. Equation 2: Why do you denote r_g as effective radius? It should be the modal radius (which needs not be the same), shouldn't it? Or is this the case in a 1-modal distribution? For simplicity's sake there is only one mode.

For clarity, text has been added on page 10 line 254 following the sentence, “... standard deviation, respectively”, which reads “ r_g and σ_g are the radius and standard deviation of the monomodal distribution, respectively.”

5. Page 17221: Haywood et al. (2009)? See you reference list.

Thank you for pointing this out. The reference to Haywood et al. in the reference list has been corrected to now read “Haywood et al. 2008”.

6. Page 17221: The authors refer to some SAMUM results and mention Kandler et al., Schladitz et al. Measurements by Schladitz were restricted to comparably small particle radii (less than 5 micrometer). Please outline in more detail the fact that coarse mode particles of dust are considerably larger than 10-15 micrometer. See for example the results by Weinzierl et al. (TELLUS special issue on SAMUM 2006). In how far are these results in agreement with the description of VMD (As outlined by Reid et al. 2003b, 2008)?

Text has been added to show that coarse mode dust particles can be larger in size as reported by Weinzierl et al. 2009 (e.g., Fig 13). The results appear to be consistent at least

on the higher end of those outlined by Reid et al. The reason for this is likely due to using different measurement techniques. For example, Weinzierl et al. employ various measurements including those from optical particle counters (OPC), whereas other strategies rely on aerodynamic (e.g., APS) and optical inversion methods (e.g., sun photometers). Reid et al. 2003 showed that large differences can exist between these different methods.

On page 11 line 261, the following text has been updated to read as: “The computed VMD for this study include: 1.6, 3.0, 6.0, 9.0, 12.0, 18, and 20 μm , although most observations place the VMD of coarse-mode dust in the 1.5-9 μm range with a majority of reported values between 3-6 μm (J.S. Reid et al. 2003 and 2008). As a note during SAMUM 2006, Weinzierl et al. (2009) reported averaged VMD values of $15.5 \pm 10.9\mu\text{m}$, where giant sized particles (20-40 μm) were found about 70% of the time. Direct comparisons of particle sizes in literature must be exercised with caution however, due to differences in measurement techniques (Reid et al. 2003).”

7. Page 17222, 17232, 17251: you refer to “Farmer”. The reference is missing.

Thank you for pointing this out. The reference has been added.

8. Eq. 3, page 17223: Does this mean that volume equivalence has been chosen? This is not entirely clear. The choice of size equivalence has a large impact on the optical properties of non-spherical properties! See reference: Otto et al. (2009).

Yes, volume equivalence was used in this work. To clarify this important point, text was added on page 13, line 310 to read as follows: “...extinction coefficient (β_e – in units of cm^{-1}) for dust, assuming volume equivalence (refer to Otto et al. 2009), can be...”

9. page 17225: $N=12$ might be too small. The authors show comparisons to orientation angles of 1050. Please refer to the work by Worringer et al., AO, 2007. The authors show that 343 angles are required. But this depends on the modeled particles and their index of refraction.

We choose $N=12$ considering the lengthy computational time of DDA, particularly over the wavelength and size domains being investigated. To identify any associated error with using restricted angular orientations, an experiment was conducted by comparing the MEE for a test particle after being rotated through a total of 12 and then 1050 Euler angles. The results indicated (please see Figure 2 of manuscript) that the errors should not exceed $\text{MEE} = 0.08 \text{ m}^2 \text{ g}^{-1}$ when using a restricted number of integration angles for the cases examined. As the referee points out, this number depends on the modeled system, such as the symmetry and dielectric constants of the particles. As a note, the former constraint was relaxed by choosing particles with more symmetric geometries.

10. page 17237: Please reconsider your rather generalizing comment that the optical properties at 870nm are representative for the visible spectral region down to 500nm, see

for instance T. Mueller et al., Tellus Special issue on SAMUM, 2009 and D. Mueller et al., JGR 2010.

The text was updated on page 16, lines 374-378 to emphasize the spectral dependence of dust optical properties at visible wavelengths. Original text – “Because dust tends to be spectrally flat in the visible, $\lambda=0.87\mu\text{m}$ can represent wavelengths down through the green and its use avoids the extreme computational cost at the shorter wavelengths.” Updated text - “Although dust optical properties exhibit a spectral dependence at the visible wavelengths (e.g., Müller et al. 2009), we use the properties at $\lambda=0.870\mu\text{m}$ as a proxy for representing wavelengths down through the green to avoid the extreme computational cost at the shorter wavelengths.”

Similarly, the text was also updated on page 701, lines 701-704. The text now reads, “Although dust optical properties exhibit a spectral dependence at the visible wavelengths (e.g., Müller et al. 2009), the properties at $\lambda=0.870\mu\text{m}$ are used as a proxy for representing wavelengths down through the green to estimate the optical properties across the visible-IR spectrum.”

11. Eq. 8: I do not fully understand this equation. What is the wavelength summation?

The wavelength summation is not pertinent and has been removed.

12. page 17228, 17235: Reference Shettle and Fenn is missing in reference list.

Thank you for pointing this out. The reference has been added.

13. page 17230: Reference Hudson et al. is missing in reference list.

Thank you for pointing this out. The reference has been added.

14. page 17231: It is not clear which quantity is kept constant in the transition from number to volume concentration and in the variation of VMD. a) $V_{\text{tot}}=\text{const.}$ ($M_{\text{tot}}=\text{const.}$) or b) $N_{\text{tot}}=\text{const.}$...

This influences the behavior of MEE as a function of VMD (increasing or decreasing). In the case of $N_{\text{tot}}=\text{const.}$, an increasing VMD leads to an increased number of large particles, which increases MEE, contrary to what is stated here. On the other hand, if $V_{\text{tot}}=\text{const.}$, then a larger VMD reduces the number of large particles and consequently MEE. But what is essential with respect to field measurements? Is it not the number concentration that is measured? (Or is it not in the case of particle losses?) What would this imply for the a variation of VMD. N_{tot} should be a constant, which is not what has been done here.

N_{tot} is kept constant for the number to volume transitions and in the variation of VMD. This point has been made clearer by adding text on page 10, line 253 to read, “...where N is the particle number concentration (held constant in the number to volume

transition)...” Similarly, line 261 on page 11 has been updated to read, “The computed VMD for this study include: 1.6, 3.0, 6.0, 9.0, 12.0, 18, and 20 μ m, where N is held constant in the variation of VMD.”

At the shorter wavelengths, we see trends in MEE as a function of VMD for spherical particles that are consistent with those reported in Reid et al. 2003, i.e. as VMD goes up, the MEE decreases; however non-spherical effects appear to play a role in the MEE (VMD) response curves. Non-spherical MEE values at larger VMD do not fall off as quickly as do spheres; hence we see larger MEE values for particles with higher VMD. Likewise, in the thermal IR we see similar effects, where MEE values generally appear to be larger with VMD (i.e. they do not fall off with size as quickly as they do at the shorter wavelengths) and in fact at times, the MEE clearly increase with VMD as in the case of kaolinite, for example. The MEE (VMD) response in the thermal IR yields interesting physics which seems to be strongly tied with the particles’ composition and wavelength.

15. Section 5 (discussion) is not really needed as a separate discussion. You can place the text into the previous section.

Per the referee’s recommendation, the discussion in section 5 will be moved into the previous section (section 4).

16. References DeVoe and Redelsperger are not mentioned in the text.

Thank you for pointing this out. The reference DeVoe has been removed from the reference list and the reference Redelsperger has been added to the text on page 11, line 257 (i.e., Schladitz et al. 2009 and AMMA (Redelsperger et al. 2006)...).

17. Table 1: Reference Drummond missing in list?

Thank you for pointing this out. Inadvertently, the reference ‘Drumond’ in table 1 was misspelled and should be ‘Drummond’ as it appears in the list.

18. The authors may want to show a comparison of the mineral composition found during the different field campaigns in their paper (AMM; PRIDE, SAMUM, ASIAN DUST). It would help in evaluation the findings of their study.

Comparisons of the mineral compositions found during the field campaigns addressed in the paper will be added to help support the findings in this study.