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Interactive Comment

Interactive comment on "Multiple scattering in a dense aerosol atmosphere" *by* S. Mukai et al.

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Q1:

Section 4 has just three pages and is meant to contain the main scientific results of this manuscript. These three pages seem not to be in balance with the lengthy derivation (9 pages) of the formulas in section 3.1. More material should be added to Section 4, for example - intercomparison of the MSOS code for semi-infinite medium with other exact and well-tested methods - assessment of the errors of the proposed retrieval scheme - sensitivity studies - comparison with other retrieval studies in the scientific literature having similar focus (optically dense case)

A1:

The comparison of MSOS code with 'doubling adding' code is interpreted in the 1st paragraph in Section 4 as follows; the solid and dotted curves in Figure 2 represent the numerical values of total reflection from the finite atmosphere model with aerosol optical thickness (AOT) in a wavelength of 0.55 μm (Mukai et al. (2010)). Other parameters in calculations are shown within the figure. The double-circle and the filled-square in Fig. 2 represent the same reflection values calculated by our MSOS-method based on eq. (43) for the semi-finite atmosphere model. It is shown from Fig. 2 that the reflection from the finite atmosphere model converges in accordance with the aerosol optical thickness on the reflection value from the semi-infinite model. This work intends to develop an efficient algorithm for calculating the multiple scattering processes in such an optically thick atmosphere as the aerosol event. On the other hand, the MSOS is available for calculations of the radiation field reflected from the semi-infinite model. Therefore, it is shown from Fig.2 that our MSOS is a required efficient method for calculating the total reflection from an optically thick atmosphere model.

Q2:

It is strongly suggested that the authors provide an intercomparison of their semifinite medium MSOS code results with other well-accepted and verified codes (such as DISORT or an adding-doubling scheme). To achieve this, some plausible scenarios should be chosen which are representative for the dense aerosol atmosphere situation (optical depth, wavelength, solar zenith angle, observation viewing angle and surface albedo), since this type of application is the main focus of the manuscript. Please provide the following information with respect to the radiative transfer solver:

- Details on the inputs required for running MSOS
- How many orders of scattering need to be considered for reaching a particular accuracy/
- Specify how many Fourier expansion terms had to be considered. How does the

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number of Fourier terms change with optical depth and with the anisotropy of the scattering phase function?

- CPU time of MSOS versus CPU requirements for other well-established radiative transfer solvers.
- Specify the single scattering albedo ω as used in Section 4.
- Specify the aerosol optical depths at 460 nm and 550 nm for the AERONET sites A, B. This should then give the physical motivation for the optically dense aerosol situation.

A2:

MSOS is required a parameter set included wavelength, size distribution and refractive indices. Please refer to the interpretation descrived below eq.(44) on running the MSOS.

Q 3: p. 898: The retrieval of the refractive indices is not acceptable, because in principle all four parameters n and k for 550 nm and for 460 nm have to be considered. Here the authors only perturb k(460 nm). The retrieval procedure is thus not convincing. The authors are asked to treat the perturbations of the other free parameters, too, together with a discussion of the associated results/errors.

A3:

Because it is shown from the AERONET data (Eck et al, 1999) that the carbonaceous aerosols strongly absorb the short wavelength radiation, and the 460 nm band is the shortest wavelength channel of the MODIS.

Q4:

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Section 4 and the scientific results: Regarding the satellite remote sensing aspect for the retrieval of geophysical parameters for biomass burning aerosols it appears that with MODIS alone no such retrieval would be possible, since there is no constraint for (n, k) at the two wavelengths (460 nm, 550 nm). Thus, AERONET ground-based measurements play a vital role to find appropriate restrictions for (n, k) for the single biomass burning case considered here. In fact, the authors make no attempt to assess the errors of their retrieval approach. The situation for the error assessment is rather complex since, for example, errors for the AERONET products for (n, k) need also to be considered. In addition to this, uncertainties related to the "fixed" volume size distribution parameters (r_f, σ_f), (r_c, σ_c) need to be specified together with their impact on the "retrieved" value for k(460 nm). It is recommended that the authors add more material that could support accuracy and reliability of their retrieval method, together with possible uncertainties of the proposed approach.

A4:

Regarding the satellite remote sensing aspect in general for the retrieval of aerosol characteristics, much wide variety of aerosol parameters should be required (Mukai et al, 1992). In this work, however, an efficient and practical algorithm to retrieve biomass burning aerosols is desired. Therefore, intrinsic parameters as size or refractive index of aerosols are considered here alone.

Q5:

p. 884-885: Please describe the steps involved when going from the integro differential equation (1) to the functional equation (3) which involves the source function J. What is the operator Γ_r as opposed to the operator Γ ? Please give the definition for the occurring operator(s).

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Λ represent the usual Λ-operator defined by Busbridge or Sobolev et al.

Q6:

p. 887, line 8: Nothing is said about the variable A. How can it be obtained? What is meant by "independent on albedo" ? Does "albedo" relate to the single scattering albedo, not to be confused with the surface albedo?

A6:

The vaiable A is a coeffient defined by eq.(40).

Q7:

p. 894, line 8: There is no defining equation for the term $d(\Omega, \Omega_0)$.

A7:

The term $d(\Omega, \Omega_0)$ are derived from eq.(41),

Q8:

p. 897, lines 5-12: Please give more information on how the parameters (r_f, σ_f), (r_c, σ_c) have been estimated. Clearly make reference to the data of Omar et al. (2005) for the fine and coarse modes; also describe the procedure for the averaging; was the latter just the arithmetic mean, or was it something else? Please give a physically/mathematically based explanation how $\sigma_f = 1.86$ and $\sigma_c = 2.34$ are obtained from the values given for $\sigma_{f,i}$, $\sigma_{c,i}$ (i = 1, ...,6) in the authors' Table 1.

A8:

The AERONET data is analyzed by k-means method (Omar et al, 2005), and is classi-

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fied 6 categories. In this work, rf and rc are derived from the average of all categories, and f, c are decide most large deviation from rf and rc. Detail of these parameters is described in Yokomae et al, 2011.

Q9:

p. 906, Figure 3: Case C cannot be found in this figure. Why? Please also correct the typo [R(lambda p) in the caption of this figure.

A9:

The case-C is far away from the satellite data of S1 and S2 in the two-channel diagram.

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 881, 2012.

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