Atmos. Chem. Phys. Discuss., 7, S1020–S1027, 2007
www.atmos-chem-phys-discuss.net/7/S1020/2007/

Atmospheric Chemistry and Physics Discussions

ACPD

7, S1020–S1027, 2007

Interactive Comment

Interactive comment on "Simulation study of the aerosol information content in OMI spectral reflectance measurements" *by* B. Veihelmann et al.

B. Veihelmann et al.

Received and published: 5 April 2007

Response to reviewer #1

We would like to thank the reviewer for his effort to carefully go through the manuscript and for his comments.

Main comments:

1. PCA and aerosol retrieval

The reviewer points out that the results of the retrieval and also of the PCA depend on the assumptions made regarding the surface albedo and the aerosol parameter ranges considered.

The reviewer correctly remarks that the information content of OMI measurements is not sufficient to allow an independent retrieval of all relevant aerosol parameters.

The retrieval results of the multi-wavelength algorithm crucially indeed depend on the a priori knowledge about the surface albedo and on the cloud screening scheme. The cloud screening scheme applied is based on a carefully chosen set of thresholds applied to the spatial homogeneity of the scene, on the effective cloud fraction from the OMI O2-O2 cloud product and on the aerosol absorbing index. This combination of criteria makes the cloud screening scheme efficient. We note that the presence of remaining undetected clouds like thin cirrus cannot be ruled out completely. Currently, errors in the surface albedo are the most important limitations for accurate aerosol retrievals, especially over land. We would like to note that an improved surface albedo climatology is currently under construction which is expected to be a major important on that issue. For the present study that surface albedo is of less importance: we have shown that by performing PCA analyses for a variety of surface albedo spectra that the results are largely independent from the surface albedo.

The fact that the information content of OMI measurements is not sufficient to allow an independent retrieval of all relevant aerosol parameters is the starting point of the present analysis: The basic idea of performing a PCA is to quantify the number of aerosol parameters that can be determined independently.

==> A paragraph has been added to the introduction highlighting these limitations and the purpose of the PCA in this context. We have clarified that a basic assumption in this study is that the parameter ranges of the aerosol models used in the PCA cover the natural variability of atmospheric aerosol. The assumptions made regarding the aerosol parameter ranges are discussed below.

1.1 Aerosol models and parameter ranges (main comments 1.1 and 1.4 minor comment 3)

The reviewer questions the applicability of the assumptions made regarding the range

ACPD

7, S1020–S1027, 2007

of aerosol parameters and the choice of aerosol models considered.

The values and ranges of the aerosol parameter of the aerosol models are mainly based on the set of aerosol models discussed in Torres et al. [2002b]. The models chosen by Torres et al. [2002b] are grouped in five main aerosol types: urban-industrial, carbonaceous, desert dust, oceanic, and volcanic aerosol. The parameters of the models have been based amongst others long-term Aerosol Robotic Network (AERONET) sun-photometer observations [Dubovik et al., 2002] for biomass burning, desert dust, urban-industrial aerosol. Values for the wavelength-dependent imaginary part of the refractive index for desert dust aerosol have been taken from Sinyuk et al. [1993]. Data from Bauman, [2000] have been used for characterizing stratospheric volcanic aerosol. As compared to what is given in Torres et al. [2002b] the upper limit of the aerosol optical depth (AOT) of desert dust has been extended to 10 in order to account for intense dust storms directly at the source. The impact of the choice of the AOT range on the results of the PCA analysis is discussed in Section 4.2 (last alinea). Models for strongly absorbing desert dust have been included in order to account for the variability in terms of the absorption. The imaginary part of the refractive index of these models is an average of the values reported by Sinyuk et al. [1993] and the high values reported by Patterson et al. [1997]. The main types urban and oceanic aerosol have been combined to the main type weakly absorbing. This choice has been made based on what can be distinguished by the OMI instrument. We agree that the absorption of the models 1301, 1302 and 1303 is rather high for being labelled as weakly absorbing. However we note that this has no impact on the results of the PCA.

==> A discussion on the aerosol model parameter choice and related references has been added to the manuscript.

The size distributions of the models are parameterized as bimodal lognormal distributions, where each mode is defined as a lognormal number distribution with the parameters rg and sigma;. These parameters are listed in Table 2 (an error in the table header has been removed: reff and veff have been changed to rg and sigma. In contrast, AERONET analyses such as Dubovik et al. [2002] and Eck et al., [2003] report size parameters rg and sigma; of lognormal volume distributions. This explains the apparent discrepancy between the values listed in this study and the literature values such as the AERONET analyses mentioned.

1.2 Non-sphericity

The reviewer questions the applicability of the spherical shape approximation.

We agree with the referee in the assumption that accounting for non-sphericity in the desert dust models will have an impact on the retrieved values of AOT and the SSA. However, we assume that the results of the PCA using the currently available aerosol model which are based on the sphericity assumption already give a valuable information about the DFS, and the capabilities of the multi-wavelength algorithm to distinguish aerosol types and to separated.

==> We have included a paragraph with a detailed discussion in the manuscript on this subject:

The phase function predicted by Mie theory overestimates the phase function of irregular dust particles at scattering angles close to the backward scattering direction and underestimates the phase function at sideward scattering angles [Volten et al., 2001]. The cross section of scattering and absorption of irregularly shaped particles with sizes comparable to the wavelength are overestimated by Mie theory. For single-viewing instruments such as OMI, this can cause biases in the retrieved aerosol parameters such as AOT [Mishchenko et al. 1995; Masuda et al., 2002] and SSA [Veihelmann et al., 2004]. We note that it is envisaged to generate aerosol models for desert dust taking into account particle non-sphericity. Hereby the irregular shaped particles will be approximated by an ensemble of randomly oriented spheroids. Scaling effects in the reflectance spectra related to the deviation of cross sections and the phase functions of mineral dust from the Mie prediction are small compared to the scaling effects due to the variability of AOT and SSA of the models used for the PCA Therefore the

ACPD

7, S1020–S1027, 2007

Interactive Comment

number of DFS is not crucially affected by the spherical shape approximation. The impact of non-sphericity on the results of the present analysis concerning individual desert dust models is small if the shape effect on the aerosol optical characteristics is small compared to the effect of the strong absorption of mineral dust in the UV. Since this absorption in the UV is a very prominent characteristic of mineral dust, we assume that the results of the present analysis provide a good indication for the way the multi-wavelength algorithm treats non-spherical desert dust aerosol. We note that it is envisaged to generate aerosol models for desert dust taking into account particle non-sphericity. Hereby the irregular shaped particles will be approximated by an ensemble of randomly oriented spheroids.

1.3 Surface albedo

The reviewer points out that there are cases where the surface albedo spectrum takes values of up to 0.2 and criticises the choice of surface albedo spectra use in the present study.

Surface albedo spectra with values of up to 0.2 are found in rare cases in desert regions. Such extreme cases are a worst case scenario for the multi-wavelength aerosol retrieval algorithm since the contribution of surface reflection to the measured reflectance is large. The present study aims more at average cases with less extreme surface albedos.

==$>$ In order to clarify this we have added a paragraph explaining that the present study aims at average cases, excluding scenarios with extremely high surface albedo values and that errors in the assumed surface albedo spectrum larger than 0.01 in terms of absolute values are expected to occur predominantly at very bright areas in desert regions.

Naturally, the accuracy of retrieved aerosol parameters crucially depends on the accuracy of the surface albedo spectrum taken from a seasonal geographical surface albedo climatology. Currently in our group the effort is made to generate an improved

ACPD

7, S1020–S1027, 2007

Interactive Comment

EGU

surface albedo climatology to be used in the multi-wavelength algorithm. The update of the surface albedo climatology is expected to be one of the most important improvements to be made on the retrieval scheme. However, we would like to point out that for the present study the surface albedo is of less importance: We have shown that the results of the PCA - in particular the number of DFS and the principal components themselves - do not depend significantly on the surface albedo. Hereby we have taken variations of the surface albedo into account that include ocean, desert and vegetation surfaces. This makes us confident that the results of the PCA regarding number of DFS and separability of parameters are not significantly different when the surface albedo takes values up to 0.1; with this most cases that we want to cover with the present study are taken into account.

1.4 Aerosol models

See Section 1.1 of the major comments.

2. PCA interpretation

The reviewers doubt that individual aerosol parameters can be associated with individual principal components. We agree with the reviewer; in fact we do not claim this anywhere in the manuscript. Rather, we infer information about the correlation or independence of retrieved aerosol parameters. For example we derive that the measurement contains independent information about AOT and SSA (in a specific range) form the fact that these aerosol parameters are near-orthogonal in the PC space. This does not require that either AOT or SSA be parallel to a PC.

3. Practical usage of the PCA.

It is envisaged that the number of DFS will be provided as diagnostic information in the level-2 product. When less than 3 DFS are available, a warning flag will be set indicating the possibility that retrieved aerosol parameters are correlated.

Minor Comments:

1. Mineral dust aerosol absorbs strongly in the UV and less in the visible. In contrast, the refractive index of biomass burning and weakly absorbing aerosols is assumed to be constant in the wavelength region used by OMAERO. This facilitates the distinction between mineral dust aerosol and other aerosol types. Note that strongly absorbing and weakly absorbing aerosols can be distinguished also when the absorption is wavelength independent. This can be seen from the results of the PCA for the main types weakly absorbing and biomass burning aerosol.

2. The obsolete reference has been removed.

3. Weakly absorbing aerosol model: See Section 1.1 of the major comments.

4. The term Earth's radiance has been introduced at first instance. The manuscript has been checked and modified where necessary.

References added to the manuscript

Bauman, J., Stratospheric Aerosol Climatology Derived from Satellite Solar Occultation and Infrared Emission Measurements, Phd Thesis, Institute for Terrestrial and Planetary Atmospheres, State University of New York, Stony Brook, 2000.

Dubovik, O., B.N. Holben, T.F. Eck, A. Smirnov, Y.J. Kaufman, M.D. King, D. Tanré, I. Slutsker, Variability of Absorption and Optical Properties of Key Aerosol Types Observed in Worldwide Locations, Journal of Atmospheric Sciences, vol. 59, Issue 3, pp.590-608, 2002.

Patterson, E.M., D.A. Gillette, and B.H. Stockton, Complex index of refraction between 300 and 700 nm for Saharan aerosol, J. Geophys. Res., 82, 3153-3160, 1977.

Sinyuk, A., O. Torres, O. Dubovik, Combined use of satellite and surface observations to infer the imaginary part of the refractive index of Saharan dust, Geophys. Res. Lett., Vol. 30, doi:10.1029/2002GL016189, 2003.

Other references

ACPD

7, S1020–S1027, 2007

Interactive Comment

Eck, T.F., B.N. Holben, D.E. Ward, M.M. Mukelabai, O. Dubovik, A. Smirnov, J.S. Schafer, N.C. Hsu, S.J. Piketh, A. Queface, J. Le Roux, R.J. Swap, I. Slutsker, Variability of biomass burning aerosol optical characteristics in southern Africa during the SAFARI 2000 dry season campaign and a comparison of single scattering albedo estimates from radiometric measurements, Journal of Geophysical Research (Atmospheres), Volume 108, Issue D13, pp. SAF 13-1, CiteID 8477, DOI 10.1029/2002JD002321, 2003.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 1785, 2007.