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Interactive Comment

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

Anonymous Referee #1

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"Simulation Study of the Aerosol Information Content in OMI Spectral Reflectance Measurements"

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In this paper, a Principal Component Analysis (PCA) is performed to quantify the information content of OMI reflectance measurements on aerosols. This analysis is applied to synthetic reflectance measurements for desert dust, biomass burning aerosols, and weakly absorbing anthropogenic aerosol with a variety of aerosol optical thicknesses, aerosol layer altitudes, refractive indices and size distributions. The clarification of the information content of OMI observations in respect to aerosol retrievals is an interest-

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ing aspect for broad aerosol community and it is relevant to problematic of Atmospheric Chemistry and Physics (ACP). Therefore both the subject and content of the paper are appropriate for ACP. However, I found that some important discussions and clarifications are missing and need to be added in order to make paper publishable in ACP. I have listed the detailed comments below.

I RECOMMEND this paper for publication provided the main concerns are addressed.

Main Comments:

1. Assumptions Principal Component Analysis (PCA) is a powerful tool that helps to clarify the number of parameters that can be retrieved from the given set of observations. This approach is particularly useful for the analysis of the large measurement sets where direct physical analysis is difficult due to high number of measured and retrieved parameters. In these regards, the situation with the retrieval of aerosol properties from satellite observations is significantly different. For example, it is clear without any analysis that OMI measurements are not sufficient for retrieval of all aerosol parameters (optical thickness, shape of size distribution, complex refractive index, particle shape and aerosol vertical distribution) and surface reflectance parameters. Therefore, only some of aerosol parameters can be retrieved if the surface reflectance and the rest of aerosol parameters are assumed a priori. Therefore, the accuracy of final retrieval, FIRST OF ALL, depends on the accuracy of the a priori assumptions. The same statement is largely applicable to interpretation of PCA information content analysis, because PCA is applied to synthetic data set produced using assumptions about aerosol and surface properties. Correspondingly, value of PCA analysis critically depends on the assumptions accuracy. This is why, I believe that the detailed discussion of all assumption employed is necessary for making the conclusions of PCA analysis convincing. Unfortunately, in this paper several assumptions made prior PCA analysis are questionable and not well explained neither justified. For example, I see the issues with the following assumptions:

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1.1 Aerosol parameter range. At the page 1794 (section 5), the authors say “The range of aerosol parameters is representative for the natural variability of aerosol and is chosen based on AERONET data [Holben et al., 1998]. With the range of refractive indices considered, the SSA of the aerosol ranges between 0.8 and 1. The effective radius reff of the bi-modal size distributions [for definition Hansen and Travis, 1974] varies between 0.1 ?m and 0.8 ?m”. It is not clear how actually the authors came out with such variability. The cited paper [Holben et al., 1998] gives only general description of AERONET network and does not show any climatology on either optical depth or size distributions. SSA is not mentioned at all in Holben et al., 1998. For example, the authors consider values of AOT up to 10. I do not believe they do it based on AERONET data, since there are no such high values in AERONET data base (˜4 is probably maximim). I think both more detailed discussion and more appropriate referencing are needed.

1.2 Assumption of spherical particles for desert dust aerosol. At the page 1974 (sections 20 -21), the authors state “The non-sphericity of desert dust is not taken into account in this study. 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]. For single-viewing instruments such as OMI, this can cause biases in the retrieved AOT [Mishchenko et al. 1995; Masuda et al., 2002; Veihelmann et al., 2004]. When the variability of single-view reflectance spectra is analyzed using PCA, such scaling effects are of minor importance. In this context, the most important characteristic of desert dust in OMI reflectance spectra is the absorption in the ultraviolet, which is taken into account in the desert dust model. Therefore, we assume that non-sphericity of desert dust particles has a minor impact on the information content of OMI reflectance measurements estimated in the present study.”

This statement is not convincing. FIRST, the references are given for AOT retrievals only, while the authors consider the retrieval of at least two parameters (AOT and SSA).

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Since, the phase function depends on both particle shape and complex refractive index (especially for spherical particles) then error in particle shape may affect both AOT and SSA and simple interpretation of retrieval errors may be difficult. I believe more detailed discussion and may be some illustrations are desirable. For example, I found that studies by Sinuyk et al. [2003, Combined use of satellite and surface observations to infer the imaginary part of refractive index of Saharan dust, J. Geophys. Res. Lett., 30, 10.1029/2002GL016189] indicate sensitivity of TOMS retrieval to particle nonsphericity and OMI should be even more sensitive to particle shape because of wider spectral range of the measurements. SECOND, the authors emphasize the importance of correct choice of desert dust absorption model, but they do not explain how they have chosen desert dust, as well as, other models.

1.3 Surface albedo At the page 1801, Section 4.6, the authors state that the error in their assumption of surface reflectance is 0.01. I think this is strongly underestimated evaluation. For example, in Fig.7 the highest value of soil surface reflectance at 500nm is 0.07, while it is known that in visible the reflectance of bright surfaces is much higher. For example, measurements of desert dust surface reflectance (e.g see Soulen et al. 2000: Airborne spectral measurements of surface-atmosphere anisotropy during the SCAR-A, Kuwait oil fire, and TARFOX experiments J. Geophys. Res., 105 (D8), pp. 10203-10218) show values of 0.2 for surface reflectance at 500 nm. By the way, in such conditions, the satellite retrieval has been proven to be most difficult (e.g. for MODIS, see Kaufman et al1997: Operational remote sensing of tropospheric aerosol over land from EOS moderate resolution imaging spectroradiometer. J. Geophys. Res., 102, 17051-17067). I think the authors should revise their surface assumptions and include a discussion how those assumptions were chosen. This is PARTICULARLY IMPORTANT, since without appropriate assumption on surface reflectance of bright surfaces the correct aerosol retrieval can be achieved. NOTE that in case of TOMS the situation is different since all surfaces are rather dark in UV.

1.4 Aerosol models. The authors show the used aerosol models in Table 2, however

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there is no discussion where these models are coming from and how they were chosen. I think this needs to be included especially for absorption assumed for different aerosols. Proper referencing is needed. (I see different absorption values for biomass burning and desert dust, but the choice of the models is not explained.)

2. PCA interpretation. The authors in their analysis closely follow the methodology described by Tanre et al. [1996], however I found a substantial deficiency in using PCA compare to the study by Tanre et al. [1996]. Specifically, the authors directly associate the principle components give by PCA with actual physical parameters such as TAU and SSA. I am not convinced that such simple transition from PC to retrieved parameters is correct. To my understanding the principle components are not directly related with specific aerosol or surface parameters, but they rather can correspond to any linear combinations of these parameters. Therefore, there is a need of discussion about possible interpretation of the PCA analysis results, because independence of some linear combination of parameters does not guarantee the independence of the parameters by themselves. Tanre et al. [1996] spent substantial efforts on interpretation of principle components that helped to make some practical conclusions for MODIS application, while this study does not discuss this aspect at all.

3. Practical usage of the PCA results. It is not completely clear from the paper how PCA results will be included in actual OMI retrieval. If the number of principal components changes depending on situation, how this fact will be reflected in the OMI algorithm?

Minor Comments:

1. Page 1788, sections 15-12: “Mineral dust aerosol can be distinguished from other aerosol types due to the absorption of mineral particles in the UV.” I am not sure if this statement is correct. I think TOMS can only distinguish between absorbing and non-absorbing aerosols, while the aerosol type should be assumed. Please, check!

2. References. In the text I did not find any mention of the paper by Dubovik and King. It should be removed from the list.

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3. Table 2. The author call "weakly absorbing aerosol" the model with imaginary part 0.012. It seems to be confusing since SSA for such model is rather low ˜ 0.9.

4. Terminology. The authors do not always use appropriate scientific terminology. For example, at the page 1788, paragraph 10, they use term "Earth radiance". I believe some explanations of this term can be helpful.

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

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