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Atmospheric Measurement Techniques Discussions

Interactive comment on "Retrieval of stratospheric aerosol density profiles from SCIAMACHY limb radiance measurements in the O_2 A-band" *by* B. Ovigneur et al.

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Anonymous Reviewer #2

We would like to thank reviewer 2 for his/her concise and instructive review of our paper. We address the concerns and queries of the referee as follows (page and figure numbers refer to the revised manuscript):

General comments:

G1: In limb scatter measurements, it is relatively easy to retrieve an effective sur-

face albedo independently by considering the limb radiance magnitude above the aerosol layers (Height>35km) and below the height range affected by straylight (typically height<45km) in spectral range outside of the main gaseous absorption regions and where Rayleigh is not too large (mostly above 500nm)

Text is adapted: We address this idea on page 8 of the revised manuscript.

G2: Confining the aerosol retrieval to the very narrow A band does not allow for retrieving any information on aerosol size, which is a major drawback specially for limb scatter sensors since the scattering properties (scatter coefficients, phase function) strongly depend on particle size distribution.

The referee comment is correct and this point is also mentioned in the revised manuscript. In the conclusion (page 15) it is stated "In the future this data may be useful to improve our knowledge on the long-term chemical evolution of the stratosphere. Nevertheless, further effort is needed for exploiting the full capability of SCIAMACHY limb measurements for stratospheric aerosol retrieval. For example, limb radiance measurements at other wavelength may provide useful information on the size of stratospheric aerosol." In that sense the presented work is a first step towards a full exploitation of the SCIAMACHY measurements. The paper focuses on the simultaneous retrieval of surface properties and aerosol particle density profiles from limb O2 A band measurements and the use of shorter wavelength will be a subject of future work.

G3: Additionally, emission in the A band along the line of sight could affect retrievals and must be accounted for in the forward model

We have added a discussion on the atmospheric emission in the O2 A-band and its relevance for the retrieval of stratospheric aerosols. For this purpose we considered SCIAMACHY limb measurements at the dark side of the orbit shortly before sunset, which shows the layer of atmospheric dayglow at about 80 km altitude. These measurements are used to estimate the relative contribution of atmospheric emission as function of altitude. (see Fig. 6 and discussion on p. 9). Subsequently, we use SCIA-

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MACHY measurements at 70 km tangent height at the dayside of the orbit to estimate the absolute contribution of emission at lower tangent heights for a given limb scan. The effect of ignoring atmospheric emission in the retrieval is estimated in Fig. 8 and discussed on page 13 of the revised version of the manuscript. It is typically below 5 %.

G4: The results presented in the paper show comparison with SAGE II aerosol products on the order of 30-50% RMS after adjustment for size distribution. Better results can be obtained for aerosols from limb scatter measurements by independently retrieving extinctions over a larger range of wavelengths (from 500 nm to 1000nm). This method allows one to infer the value of an effective Angstrom coefficient, which can then be used iteratively to improve the retrieval of aerosol vertical distribution. This method has been tested over large datasets and is being implemented in the OMPS/LP program. Application of this method to the SCIAMACHY dataset have been described by Taha et al.

We are not sure what the reviewer suggestion is. We agree with the reviewer that limb measurements at other wavelengths can provide useful information on the microphysical properties of the stratospheric aerosol. This is clearly stated in the conclusion of the manuscript as an important issue for future work. The main aspect of the presented manuscript is the simultaneous retrieval of surface albedo and stratospheric aerosol concentrations. In that sense it differs from earlier work and may provide new insights in stratospheric aerosol retrieval. The reviewer refers to the work of Taha et al. and we agree that the presented retrieval method seems to work for SCIAMACHY measurements, which is very promising. However, as shown in the paper of Taha, the comparison of their SCIAMACHY aerosol profiles with SAGE II profiles is not bias free and it also shows a significant data spread. It would be very interesting to compare both retrieval performances in more depth and we are convinced that both retrieval approaches may benefit from such an exercise. However, this goes beyond the scope of the presented study.

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G5 There is no error analysis. We must expect some error analysis in this journal article. Need comments on the covariance matrix, estimates of the standard deviation evaluated as square root of covariance matrix There is hint at error magnitude when talking about the 'unexplainable' spread of 0.1 particlescm-3 its monthly running value of 0.3 particlescm-3, that is accounted to "the effect of measurement biases and forward model errors on the retrieval". That is a $\pm$30 percent error RMS.

Adapted: We provide a short discussion on the mathematical background to derive the retrieval noise from the measurement error covariance. On page 15, an instrument model is presented which provides the SNR of a measurement simulation. Subsequently, on page 16 the retrieval noise as function of scattering angle (Fig. 12) is discussed. The error analysis is done on simulated measurements with a realistic estimate of the measurement noise to investigate the retrieval noise as function of scattering angle, which is the most critical parameter in this context. Due to the choice of low surface albedo the estimate provide a upper threshold of the retrieval noise.

Specific comments:

S1: In Fig. 6. (Second panel): Lambertian surface albedo retrieved at 500 nm. How is this retrieval done? The paper does not discuss the retrieval at 500nm? I guess assuming no wavelength dependence on albedo? Though the text mentioned "surface albedo is determined for each individual wavelength to account for the spectral variability of surface eflection". Need comments on what is assumed here?

Changed: we have rephrased this part of the manuscript to "To assess the spectral consistency of the retrieved aerosol properties, we look into the simulations of SCIAMACHY limb radiance measurements at 500 nm in the visible part of the solar spectrum. From these measurements we determine a Lambertian surface albedo using a least squares inversion. In this manner we account for the spectral variability of surface reflection between the visible and the spectral range of the O2 A band. Moreover, for the radiance simulation the aerosol properties were used, which were retrieved before-

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hand from SCIAMACHY O2 A-band measurements.

S2: The spread of the data around its monthly running value in the order of 0.1 particles cm-3. The author states that this is significantly above the retrieval noise level <1% at the altitude range 14–30 km. What does that mean? There is no mention of sensitivity of limb radiance to aerosol: A 100% fluctuation in aerosol could lead to a 1% in radiance magnitude at some wavelengths.

Adapted: We have introduced the definition of the retrieval noise at page 10, which is the statistical noise on the retrieved state vector due to the measurement noise. Furthermore, in Fig 12 we give an estimate of the error as function of scattering angle. We do not understand the referee's comment "100% fluctuation in aerosol could lead to a 1% in radiance magnitude at some wavelengths". This sensitivity is taken into account in the retrieval by the Jacobian K. Finally this sensitivity governs the noise propagation of the inversion as it is indicated by Eq. (3) and (4) of the revised manuscript.

S3: The authors state: "For the time series in Fig. 6 the SCIAMACHY tangent height varies only by $\pm$100m". You mean that you estimate the errors on tangent height to be less than $\pm$100 meters over the time span of the slected dataset?. If that is so, I would say that this is extremely tight for a limb sensor. I would not think that SCIAMACHY would be that accurate/consistent on pointing. You may need to double or triple that estimate. Which still allows you to make the point that "the corresponding fluctuation in the aerosol density is ... well below the observed data spread and thus we can rule out variations of the tangent height to explain this feature".

Adapted: We distinguish in the revised version of the manuscript between an error on the pointing and a variation of the tangent height see page 11)

S4: The authors state: "At this wavelength (500nm) the limb radiance has significant sensitivity to stratospheric aerosol". True and not true. At small Single Scatter angle, the limb radiance is somewhat sensitive to aerosol at 500nm, with sensitivity increasing at longer wavelengths. At larger Single Scatter angles, the limb radiance is not much

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sensitive to aerosol.

Changed: We have modified the sentence to "At this wavelength and for small scattering angles the limb radiance has significant sensitivity to stratospheric aerosol"

S5: Fig 9. One of these two plots is not necessary since, as correctly stated by the author in the text, single scattering angle and latitude are related for this sun-synchronous space platform. Keep the fig vs single scatter angle, which in fact shows that for Limb Scatter sensor, the sensitivity of limb radiance to aerosol decreases as single scatter angle increases is a rather profund fashion. It does seem from that figure that the A-band method of aerosol retrieval is limited to single scatter angle larger than 60 degrees.

Figure is changed. Indeed, it is true that the proposed algorithm shows highest accuracy for small scattering angles. This is mentioned in the manuscript and we believe it is a general feature of limb radiances. For the retrieval from the O2 A band forward model and calibrations errors become relevant at these scattering geometries. In the conclusion we provide suggestions to improve the accuracy of the retrieval in this spectral range (e.g. polarization correction. . .)

S6 The authors vary the mean radius to match with SAGE II products. How about also varying the width of the log normal distribution?

Not changed: The variance of the size distribution is of minor relevance here, especially if one takes into account the overall uncertainties of stratospheric aerosol retrieval.

S7 The authors state that "limb radiance measurements at shorter wavelength may provide useful information on the size of stratospheric aerosol". What we need is a wide range of wavelengths, therefore not only shorter wavelengths, but also longer ones. Retrieving aerosol is in fact easier at longer wavelengths as sensitivity of limb radiance to aerosol increases with wavelengths .

Changed, see conclusion " For example, limb radiance measurements at shorter

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wavelengths may provide useful information on the size of stratospheric aerosol." changed to "For example, limb radiance measurements at other wavelengths may provide useful information on the size of stratospheric aerosol."

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/4/C1030/2011/amtd-4-C1030-2011-supplement.pdf

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Interactive comment on Atmos. Meas. Tech. Discuss., 4, 1795, 2011.