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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 #1

We would like to thank reviewer 1 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 Retrieval errors: Essentially nothing is said about the retrieval errors (apart from the brief statement that the retrieval noise level is less than 1 % on page 1804). What are other sources of error? Can they be estimated, at least roughly?

In the revised version of the manuscript we provide a more detailed discussion on the retrieval noise for simulated measurements using a realistic estimate of the measurement noise. The reason to use simulated measurements is that it allows investigating the dependence of the retrieval noise as function of the scattering angle, which is the most critical parameter in this context. In more detail, on p. 10 we added 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.

Furthermore, 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 SCIAMACHY measurements at 70 km tangent height at the dayside of the orbit to estimate at 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.

G2 Sensitive altitude range: The abstract as well as the conclusions state that the aerosol profiles are retrieved in the 10 – 40 km altitude range, but the measurements are certainly not equally sensitive to stratospheric aerosols at all altitudes in this range.

Fig. 10 only shows comparisons with SAGE II up to an altitude of 29 km. Can you provide a more robust estimate on the altitude range for which the retrieval is typically sensitive to aerosols, e.g. using retrievals of synthetic limb measurements?

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We added Fig. 12 to the revised version of the manuscript, which shows the retrieval noise as function of scattering angle for a low albedo case. The Figure demonstrates that for an altitude of 18, 21 and 25 km the retrieval noise is below 4, 3.5 and 6 % for all scattering angles. For 31 km the retrieval noise increases to 25 % for large scattering angles but stays below 10 % for scattering angle < 100 degree. This demonstrates that from the perspective of retrieval noise the limb measurements in the O2 A band provide sufficient sensitivity to stratospheric aerosols in the relevant altitude range 15-30 km. The height range in Fig. 10 (now Fig. 13) is determined by the availability of SAGE data (see also point S11)

G3 A-band emission: as you mention, the A-band is also a strong emission feature starting to become important in the upper stratospheric limb spectra. Looking at Fig. 5, the emission already leads to a small local radiance maximum at 761 nm at a tangent height of 38 km, which suggests that the effect of the emission will be non-negligible probably already 10 km below that tangent height. The crucial question is what effect the emission will have on the aerosol retrievals. Can you provide an estimate on this effect? Neglecting the emission in the retrieval would produce a high bias in the retrieved aerosol densities and extinction coefficient at the upper levels. Is this seen in the retrievals when looking at altitudes higher than 30 km?

See our comment to point G2

Specific comments:

S1: Page 1798, line 4: 'The Improved Limb Atmospheric Spectrometer-II .. was successfully launched in 2002.' The sentence before this one suggests that ILAS-II was a 'limb-viewing' instrument and not a solar occultation instrument. However, I'm pretty sure ILAS-II was an occultation instrument as well. By the way, occultation instruments are also sometimes called limb-viewing instruments.

Changed, see page 4

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S2: Page 1798, line 10: ‘both launched in 2001.’ This is not true, as Envisat was launched on March 1, 2002.

Changed, see page 4

S3: Page 1798, line 13: ‘which is backscattered .. in nadir, limb and occultation geometry’. Radiation is not really backscattered in occultation geometry, is it?

Changed, see page 4

S4: Page 1799, line 23: ‘as depicted in Fig. 1’. Shouldn’t this read ‘Fig. 2’?

Changed, see page 5

S5: Page 1801, line 9: ‘requires a simultaneous fit of surface albedo and stratospheric aerosol abundances ..’ It’s perhaps worth mentioning that normalizing the limb radiances with respect to a higher tangent height will remove a significant part of the albedo sensitivity, but retains the sensitivity to stratospheric aerosols. You also indirectly note this when discussing Fig. 3.

Changed, see page 7

S6 Page 1800, lines 10 and 16: As Fig. 4 is discussed first in the text I suggest changing the order of Figs. 3 and 4.

Changed, see page 6

S6: Page 1801, line 17: ‘Thus, an increase in stratospheric aerosol at tangent height causes an increase in the amount of light travelling this path’. Strictly speaking, this is only true, if the aerosol is optically thin along the line of sight. If it becomes optically thick then increasing the amount of aerosol may not necessarily lead to an increase in limb radiance.

Adapted: The statement in the paper is correct. When we enhance the amount of aerosol at the tangent height/point, thus at an infinite volume element the single scat-

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tering source function increases and by that the signal. What the referee means is an increase of the aerosol abundance along a finite path length element. In this case, one has to integrate the single scattering source function along the line of sight. Here the tradeoff between the enhanced sources and the enhanced extinction determines the increase or even decrease of the signal. A remark is added at page 7/8

S7: Page 1801, line 22: 'This makes the simultaneous retrieval of aerosol particle density profiles and surface reflection from limb measurements at one particular wavelength in the longwave visible an ill-posed inversion problem.' I'm not convinced this statement is true. The inversion problem is certainly ill-posed in a general sense, and requires constraints. However, as the albedo sensitivity of the limb radiances is – to first order– independent of the tangent height, one can use the limb radiances in the upper stratosphere, where the contribution of stratospheric aerosols to the limb radiances should negligible, to estimate the surface albedo. In other words, use different tangent height ranges for the retrieval of surface albedo and stratospheric aerosols.

Text is adapted, see page 8

S8: Page 1804, line 9: 'Since the launch of SCIAMACHY, there has been no major volcanic eruption with significant stratospheric sulphur injection ..' This is perhaps true for tropical and subtropical latitudes, but we had the eruptions of Kasatochi in August 2008 and the one of Sarychev Peak in June 2009, that produced significant and measurable amounts of stratospheric aerosols at northern mid-latitudes.

Changed, see page 11

S9: Page 1804, line 13: You write that the retrieval noise level is less than 1 %. Does this also apply to high southern latitudes, where the aerosol signature in the limb radiances is much smaller than in the northern hemisphere, because of the aerosol phase function? I assume this is just the statistical error originating from noise on the limb radiances used. But what about other sources of error?

Changed: See our comment to G1

S10: Page 1806: Subsection ‘Comparison with SAGE II’ It would be good to state what the accuracy (at least the estimated accuracy) of the SAGE II aerosol extinction profiles is. Otherwise, it’s impossible to tell, whether a relative difference of 30 % or 50 % is problematic or not.

Changed: At page 15 and 16 we discuss the differences between SAGE II and SCIAMACHY extinction in the context of the SAGE and SCIAMACHY measurement uncertainties.

S11: Page 1806, line 15: ‘Fig. 7 shows on specific example’. I’m surprised to see that the SAGE II extinction profile goes to zero at 25 km. This cannot be a typical case. If this is rather an exception I suggest showing another example.

Not changed: We have considered the upper height threshold of non-zero aerosol extinction for a sample of 12 000 SAGE profiles covering the latitude range from 70 degree South to 70 degree North. For this sample we obtained the mean threshold height of 26 km. For only 8 % of all samples a non-zero aerosol extinction is reported above 30 km. This shows that the reported SAGE profile does not represent an exception case but a typical SAGE retrieval result.

S12: Page 1807, line 16: ‘The reduced aerosol sensitivity of the measurement for large scattering angles is also the reason for the little number of successful SCIAMACHY retrievals at the Southern Hemisphere.’ It would be useful to provide some information as to when the retrieval is successful or considered successful. What criteria have to be fulfilled? Are – for the unsuccessful retrievals – aerosol profiles produced, but then rejected after the retrieval? This should be discussed in more detail.

Changed: On page 10 of the revised version of the manuscript the convergence criterion of the Gauss-Newton iteration is discussed.

S13: Page 1808, line 21: ‘aerosol density profiles are retrieved in the height range

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10-40 km'. This suggests that SCIAMACHY provides information on stratospheric aerosols within this height range, which is most likely not correct. It's not clear what the upper limit of the sensitive altitude range is, or how important the neglected O2 emission becomes near 40 km. The emission is already clearly affecting the A-band spectra at 34 km, which must lead to a systematic effect in the retrieved aerosol densities.

This point is considered in the revised version of the manuscript. See comment to point G1.

S14: Page 1808, line 24/25: 'SCIAMACHY density profiles' -> 'SCIAMACHY aerosol density profiles'

Changed, see page 14

S15: Page 1814, Fig. 1: I suggest increasing the font size of all legends in this plot

Done

S16: Page 1815, Fig. 2: It's not entirely clear what quantity is shown here. It's certainly not limb radiance in radiance units (photons / sr / s / m2 / nm). Also, the axis labels and legends are quite small.

Adopted: the figure shows the sun normalized radiance I/Fo. The fonts of the figure are enlarged.

S17: Page 1816, Fig. 3: axis label font size should be increased

Done

S18: Page 1818, Fig. 5: Perhaps you can indicate in this plot what wavelengths are used for the retrievals (at least the wavelength within the A-band)

Changed

S19: Page 1819, Fig. 6: Font sizes of axis labels and legends are too small.

Changed

S20: Page 1822, Fig. 9: Please mention how the relative difference is defined. Is it (SAGE –SCIAMACHY) / SCIAMACHY or 2*(SAGE – SCIAMACHY) / (SAGE + SCIAMACHY)?

Changed, (SAGE-SCIAMACHY)/SAGE is added to the figure caption.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/4/C1022/2011/amtd-4-C1022-2011-supplement.pdf

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

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