

Interactive comment on “Retrieving the vertical distribution of stratospheric OCIO from Odin/OSIRIS limb-scattered sunlight measurements” by P. Krecl et al.

P. Krecl et al.

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Reply to Interactive Comment: Anonymous Referee #1

MS-Nr: acpd-2005-0072 Retrieving the vertical distribution of stratospheric OCIO from Odin/OSIRIS limb-scattered sunlight measurements

We thank anonymous referee # 1 for the constructive and helpful criticism. We have addressed to the points of referee # 1 by doing a major revision of the manuscript and clarifying all the listed points. A detailed response to the comments of reviewer # 1 follows below.

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Specific comments:

1. We agree with the referee that Section 3.1 contained information already discussed in Haley et al. (2004). Thus, this entire section has been rewritten keeping the descriptions of the residual analysis and chi-squared test that are not present in Haley et al. (2004). Figure 1 has been also removed from the manuscript.
2. Page 2994, line 18. Section 3.1 has been rewritten and this sentence does not exist any longer. Hence, the referee's comment does not apply.
3. End of Section 3.1. A comment on how to estimate the measurement noise of the OSIRIS instrument has been added.
4. Section 3.2. We agree with the referee on plotting the differential absorption cross sections multiplied by typical slant columns. Hence, the observed and fitted DOD of O₃, NO₂, O₄, Rayleigh and tilt has been added to Fig. 6 (old Fig. 7) and the old Fig. 2 has been removed.
5. Section 3.2, page 2998, Fig. 4. The observed and fitted DOD of OCIO were added to this figure (now Fig. 3) for the three windows, as suggested by the referee. The shaded region is darker than before.
6. Section 3.2, page 2998, line 16. After plotting the limb radiance signal-to-noise ratio as suggested by referee #2, it turned out that the main reason for the smaller residual structures in the 403–427 nm region could be the larger signal-to-noise ratio values for $\lambda > 400$ nm. Thus, the comment related to the cross correlation between OCIO and BrO cross sections has been removed from the text. Anyway, we agree with the referee that the cross correlation between cross sections should not increase the RMS residual since the best combination is selected to minimize the residual.
7. Section 3.2, page 2998, line 22. This paragraph was rewritten and the negative OCIO ECD were classified as undetectable as suggested by both anonymous referees.
8. Section 3.3. As suggested by the referee, the nature of the spectral corrections has

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been removed from this section and appropriate references to Haley et al. (2004) have been added to the text.

9. Section 3.3, line 11. Some comments on how to obtain the relative ECD error have been introduced.

10. Section 3.3. As suggested by the referee, the spectral corrections can be divided into two groups: a) corrections applied before the LSQ fit (I_0 , wavelength shift, and Ring), and b) corrections fitted in the LSQ fit (Rayleigh, tilt and polarization). After performing the sensitivity test for the first group, we conclude that I_0 is the only spectral correction that improves the retrieval. The second group of spectral corrections is more difficult to evaluate since they are included in the LSQ fit and can correlate with OCIO. The polarization correction does not make a significant difference when included in the OCIO retrieval as shown in the sensitivity test results. We know that the Rayleigh trending exists and is not completely removed by the second order polynomial, and we know from modelling studies that the tilt effect is a real phenomenon.

11. Section 3.3.3. We agree with the referee and this comment has been introduced in the Ring effect subsection.

12. Section 3.3.4. The figure displaying the polarization parameter has been deleted from the manuscript since this correction is not applied when retrieving OS OCIO profiles.

13. Section 3.3.5. The formula for the tilt correction used in this study differs from the one presented by Sioris et al. (2003) in two aspects. The related explanation has been introduced in the text.

14. Section 3.3.5, Calculation of the tilt pseudoabsorber. Varying the tilt with tangent height should be more correct since the trending does change with tangent height, and thus so does the spectral structure of the tilt. The mean reference tangent height is 48.2 km, taking into account the actual OS measurement tangent heights in the 40-70

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km range and calculating the appropriate representative reference tangent height for the set of 122 scans. The error produced by considering the reference tangent height at 50 km versus 48.2 km should be smaller than the error introduced when using a fixed tilt spectrum (i.e., same tilt spectrum for all tangent heights).

15. Section 3.3.6. No shifting of the reference spectrum relative to the lower tangent heights has been observed in the OS measurements. Since it is not expected that OS pixel wavelengths vary over the duration of a scan (short time period and stable temperature of OS), an absolute shift in wavelength is determined through L-M non-linear iterations on the DOAS fit to the lowest tangent height measurement and then applied to all measurements in the scan. A sentence was added to this section explaining why the derivation of the wavelength shift was carried out only at the lowermost tangent height.

16. Section 3.3.7, Figure 7. Now the DOD of the other trace gases along with Rayleigh and tilt are shown in Fig. 5 (old Fig. 7) as suggested by the referee in the comment #4.

17. Section 3.4. We agree with the referee that there are different non-linearities present in this inversion process. The non-linearity resulting from the large ozone optical depths could be a problem for retrievals in the Chappuis region, which does not apply to the 403-427 nm region used in our study. Another kind of non-linearity is produced by the non-linearity of the forward model which might be caused by Rayleigh extinction. The text in Section 3.4 has been modified in order to clarify this point.

18. Page 3007, line 3-5. A new sentence was added in Section 3.4 stating that the following discussion assumes the inversion of the concentrations for clarity reasons. Otherwise the equations will become more complicated than is necessary.

19. Section 3.4.1. We have removed the first part of this section as suggested by referee #1 and referred the reader to Haley et al. (2004) for more detailed information.

20. Section 3.4.2. As explained in the reply of comment # 18, the equations apply to

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the retrieval of n . Thus, 300% refers to the standard deviation of the a priori in a linear space, before translating it to the logarithmic space.

21. Section 3.4.3. The linear weighting functions are shown in Fig. 7. A comment was introduced in this section to clarify this point.

22. Section 3.4.3. This sentence was removed from the text since it does not add any new information. Anyway, the derivatives of the RTM refers to the derivatives of the limb radiances with respect to n .

23. Section 3.4.3. We agree with the referee and a comment has been introduced in this section clarifying that the other species are not significantly interfering with OCIO at these selected wavelengths. Whereas this interference is not very important for K calculations, it has a large influence on F calculations if the two-wavelength DOAS approach is used.

24. Section 3.4.4. The entire section has been removed as suggested by the referee.

25. Section 3.4.5. We agree with the referee and the text has been rewritten. Even though each profile retrieval is different, Fig. 8 captures what similar figures for other scans would show (i.e., good measurement sensitive between 14 and 22 km, with 2-4 km altitude resolution).

26. Section 4, Fig. 10. This figure has been removed from the manuscript. A new figure (Fig. 6) shows the sensitivity of the retrieved OCIO profile to the a priori OCIO profile in Section 3.4.2.

27. Section 4, page 3015. The comment does not apply since the old Fig. 10 has been removed.

28. Section 4, Table 8. We agree with the referee and the comment related to the shape of the OCIO profiles has been deleted. The motivation for including Table 9 (old Table 8) is to refer to the few OCIO profiles measured in balloon campaigns in other periods, not to provide direct comparison but to show that OS OCIO number density

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values are reasonable. A sentence has been introduced in this paragraph, clarifying how the OCIO volume mixing ratio (VMR) values presented by Rivière et al. (2003) were converted into number densities. Note that the measurements displayed in Table 9 (old Table 8) are balloon-borne and not ground-based as mentioned in comment #28 of referee #1.

29. Section 4, page 3015, line 20. As suggested by referee #2, the word “diurnal” has been replaced by “twilight” in this line.

30. Section 4, page 3015, line 25. As suggested by the referee # 1, the potential vorticity isoline of $-48 \times 10^{-6} \text{ K m}^2 \text{ kg}^{-1} \text{ s}^{-1}$ at the 475 K isentropic level has been plotted in the new Fig. 10 (right panel).

31. Section 4, Fig. 11. We agree with the referee and another scan (number 8565051, latitude 60.5°S , longitude 31.30E , SZA 91.50 , 17:57 LST) measured in mid-latitude air has been plotted in Fig. 9 (old Fig. 11). Since NO_2 concentrations show strong diurnal variations due to photochemistry reactions, the comparison between scan 8565051 and scan 8565047 (latitude 81.70S , longitude 36.40E , SZA 92.00 , 18:10 LST) is not masked by this effect.

32. Section 4, page 3015. While redoing calculations for this review a bug in the computations was identified. In the first version, climatological temperature profiles were used instead of using the ECMWF temperatures to convert VMR into number density for the a priori profiles. Thus, all these calculations were redone employing the ECMWF temperatures. As seen in Fig. 9 (old Fig. 11), the OCIO profile now smoothly decreases between 18 and 24 km altitude as suggested by the referee.

33. Section 4, page 3016. Reduced O_3 and NO_2 concentrations are expected inside the polar vortex area as a result of the ozone depletion, and denitrification and denoxification, respectively. Model calculations and a few measurements carried out during balloon campaigns have shown that enhanced OCIO number density profiles are observed inside the polar vortex area (e.g., Renard et al. 1997; Rivière et al. 2003).

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The motivation to present the O₃ and NO₂ profiles in Fig. 9 (old Fig. 11) is to show that enhanced OS OCIO concentrations are found in areas where reduced O₃ and NO₂ occur during the ozone 'hole' event. This also gives the opportunity to check the consistency among O₃, NO₂, and OCIO profiles retrieved from OSIRIS limb-scattered sunlight radiances.

34. Section 5, Fig. 12. We agree with the referee and the reference to Fig. 10 (old Fig.12) has been corrected in the text.

35. Section 5, page 3016, line 26. As suggested by the referee, the text has been rewritten and the reference has been changed. Fig. 10b (old Fig. 12b) shows now the OCIO profiles of two scans which are closer to each other than the ones shown in the first version. In this way, the probability of variation in the concentrations due to geolocation is reduced. The vertical integration of the scan A and scan B profiles yields now different vertical columns abundances.

36. Section 5, page 3017, line 16. We agree with the referee and the text has been rewritten, introducing a possible explanation for the non-linear relation between OCIO and CIO concentrations in twilight conditions.

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