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Atmospheric Chemistry and Physics Discussions



# *Interactive comment on* "Impact of using different ozone cross sections on ozone profile retrievals from Global Ozone Monitoring Experiment (GOME) ultraviolet measurements" *by* X. Liu et al.

**X. Liu et al.**

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We would like to thank the two anonymous referees for their comments on our paper. We have carefully considered the concerns of referee 1 (Note that there is no concern from referee 2) and have addressed them as follows and made changes in the revised manuscript.

Response to Reviewer 1

(1) Page 973: I suggest adding a reference for the general description of the HITRAN database (Rothman et al. 2005)

Response: We added a reference to HITRAN.

(2) Page 973: The study by Orphal was also published in J. Photochem. Photobiol. A 157, 2003, 185-209. I suggest including this reference since it is public access (and peer reviewed), in contrast to the ESA report, although the latter indeed contains more information.

Response: We added this reference.

(3) Page 973: "measurements characteristics of the these CS" - remove the "the" please

Response: Yes.

(4) Page 974: What was the climatology (a priori ozone and temperature profiles) used?

Response: We added "We use the ozone profile climatology by McPeters et al. (2007) as a priori to constrain the retrievals" after "aerosols, and surface albedo", added "Daily temperature profiles from the European Center for Medium range Weather Forecasting model (ECMWF) are used to reduce the effect of temperature on retrievals" after "2-3 tropospheric layers" and "Third, we switched to use daily NCEP temperature profiles for consistency during the GOME record since ECMWF temperature profiles are not publicly available after August 2002" at the end of first paragraph of section 2.

(5) Page 974: What is the typical information content (independent pieces of information) in this problem? 24 layers with 4-6 tropospheric layers are very impressive, I suggest giving also an idea what the information content is.

Response: Please see detailed characterization of information content in Liu et al. (2005). We did not discuss the information content here since it is beyond the scope of this paper. For our GOME retrievals (290-307 nm, 325-339 nm), there are 4-6.5 pieces of information in the atmosphere with up to 1.5 pieces of information in the troposphere. Retrievals are usually performed at more layers than the independent pieces of information in order to better represent the profiles.



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(6) Page 975: The convolution of cross sections was made using the variable slit widths derived in each retrieval. This is a crucial point for the paper and I do not understand why the discussion is so short here. (a) First, what did these slit widths look like and how do they vary over the orbits (and/or time for the comparisons with sondes)? The authors do have this information, so please provide it. How different are these widths for different cross sections, and how do they compare with slit functions determined otherwise? (b) Second, it looks like that the smaller fitting residuals of the BDM cross sections may be, at least in part, due to this methodology. It basically means that your algorithm works better for the BDM cross sections, but not that the BDM cross sections are better for ozone retrieval in general. This is in agreement with your observation that "these biases are significantly larger than those found by Orphal (2002)" (page 975). I agree that smaller fitting residuals mean in general a "better fit" and smaller biases mean in general "less systematic errors". However the convolution of the cross sections with the slit widths derived from the retrievals is probably a highly non-linear procedure, so I am worried now about the soundness of the conclusions.

Response: The way of deriving slit widths has been described in our previous paper (Liu et al., 2005) and the derived slit widths have been shown in that paper. So we have clarified this by changing "the derived variable slit widths in each retrieval" to "pre-determined variable slit widths by cross-correlating the solar irradiance spectra with a high-resolution solar reference spectrum" and added the reference (Liu et al., 2005) on line 11 of P975. The variation of slit widths from orbit to orbit is generally negligible. Note that the slit widths are pre-determined before the retrievals and are the same for different cross sections. So the smaller fitting residuals from BDM cross sections are not related to this methodology. The central point of this paper is to make a fair assessment of different cross sections so that the main conclusions of this study are general for other ozone profile retrievals. Independent evaluation of cross sections also found that the BDM cross sections are better for TOMS total ozone retrievals than Bass-Paur cross sections (not only reduce fitting residuals but also improve the comparison with Dobson measurements) and will be used in processing the next version (version



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9) of the TOMS data (personal communication with Pawan K. Bhartia, 2006). The reasons for "these biases are significantly larger than those found by Orphal (2002)" have already been given in the paper: This is because Orphal (2002) compared these CS at individual temperatures (temperature usually within +/-5 K between different sets) and accounted for baseline effects. The convolution of cross section with the slit widths is a standard procedure and is used in many trace gas retrieval algorithms; it definitely does not affect the soundness of this study.

(7) Page 976: The changes in residuals are small, i.e. 4-7 % relative to the fitting residuals. I suggest giving absolute numbers as well, e.g. "The fitting residuals decrease from 0.405 % to 0.401 %" so that one gets an idea how small these changes are.

Response: Because the residuals vary with latitude so we did not give the absolute numbers. The average absolute numbers are shown in Table 2. We changed "Figure 3 compares" to "Figure 3 and Table 2 compare"

(8) Page 976: Why is the effect more important in the 326-337 nm window? Isn't it a clear indication of the problem mentioned in Question No. 6 above, i.e. that you assess how well you can convolute the cross-sections (with the slit widths derived from the retrieval) in order to minimize the fitting residuals?

Response: As shown in Figure 2, the differences between different cross sections are larger in the 326-337 nm window than in the 289-307 nm window. In addition, there are large vibration structures that depend strongly on temperature. So small errors in wavelength scales or the temperature dependence can cause large fitting residuals in this fitting window.

(9) Page 976: "Unsuccessful retrievals are due to mainly negative ozone values derived at some layers" (see also my Question No. 5 above): what is the uncertainty of the ozone retrievals? Errors bars are missing in all figures. I suggest adding error bars in ALL figures showing ozone profiles and columns.



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Response: Characterization of retrieval errors has been discussed in detail in Liu et al. (2005). The retrieval errors due to random noise and smoothing are 5-10% in the stratosphere and 20-30% in the troposphere. The errors in tropospheric and total column ozone are within 3-6 DU (12-25%) and 3 DU (< 1%), respectively. Showing error bars on the figures will make some of the figures busier to read (e.g., Figures 4, 5, 7, 8).

(10) Page 977: The differences shown in Figs. 4-5 and 7-8 are in DU and not in % as in the other figures and the main part of the text. I suggest adding the relative values at least in the text so that it is easier to see what the relative differences for the total (Figure 4) and tropospheric columns (Figure 5) are. Why is the impact of different cross sections smaller for tropospheric ozone columns (Figure 5)?

Response: We have added relative differences in the text. The smaller impact (absolutely) on tropospheric ozone columns arises from the fact that tropospheric column ozone is only about 10% of the total ozone. Relatively, the impact on tropospheric ozone is much larger because total ozone is mainly determined from the 326-337 nm region, while tropospheric column ozone is determined from both the 326-337 nm window and part of the 289-307 nm window.

(11) Page 979: I agree with the inclusion of the BDM cross sections in HITRAN. However, besides the restricted temperature range of the BDM cross sections, there is another problem with the wavelength coverage. The BP and BDM cross sections do not cover wavelengths above 345 nm but ozone needs to be included at longer wavelengths when retrieving BrO, OClO, NO2 and other species. So I do not understand at all why the HITRAN panel has not yet included ozone cross sections at longer wavelengths, e.g. the GOME or SCIAMACHY data which are used exactly because of this reason in the community. I would not support including only BDM cross sections and nothing else in HITRAN, since for many other applications, an accuracy of 0.1 % is not required.



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Response: We only recommend including the BDM cross sections in the HITRAN database and did not exclude other choices for inclusion. In addition, it is beyond the scope of this paper to discuss about which cross sections should be included in HITRAN. The BDM cross sections actually cover 195-830 nm at 295 K and 195-345 nm and 515-650 nm at 218 K (Brion et al., 1998). We have corrected Table 1 for this and added the reference "Brion et al., 1998". As for the 0.1%, we meant that the Huggins bands need to be fitted to a high precision (e.g., <0.1%), i.e., high precision (not necessarily <0.1%) is required for ozone cross sections. This has already been achieved by the BDM cross section, and the fitting residuals in the Huggins bands with the Bass-Paur and GOME FM cross sections are also very close to 0.1% (Table 2 and Figure 3).

(12) Page 979: This study shows that for ozone profile retrieval from the UV data, there is need for ozone cross sections with very high accuracy (0.1%) and wavelength resolution and precision. Is this a realistic project? Wouldn't the combination of different wavelength regions in the retrievals (inclusion of the Chappuis band, inclusion of IR ozone bands) reduce this drastic requirement which is probably difficult to achieve in the near future?

Response: As described in the response above, we did not meant a high accuracy of < 0.1% but high precision in ozone cross sections so that the fitting residuals in the Huggins bands are less than 0.1%. This has already been achieved with the BDM cross sections and has almost been achieved with the Bass-Paur and GOME FM cross sections (Table 2 and Figure 3). The combination of different spectral regions will not reduce this requirement. Additionally, it requires the consistency among different spectral regions. Otherwise, the retrieval process will fight back and forth trying to fit inconsistent cross sections in different spectral regions.

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Interactive comment on Atmos. Chem. Phys. Discuss., 7, 971, 2007.