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Atmospheric Measurement Techniques Discussions

Interactive comment on "Six years of total ozone column measurements from SCIAMACHY nadir observations" *by* C. Lerot et al.

C. Lerot et al.

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The authors would like to thank both referees for their pertinent and useful comments.

Referee 1 (L. Flynn)

COMMENT: The analysis shows a trend in the differences for SGP 3.01 with other instruments' records. This is followed in the Conclusions Section by hypotheses that the source is uncorrected instrument degradation or level 0 to 1 calibration. Since one of the purposes in using a closure polynomial is to remove broad scale calibration inaccuracies, it would be interesting to see if there was a trend in this component over the six-year period. Perhaps the authors could conduct a simple experiment where the Earth-view radiances for one orbit of SCIA data are changed by a 5% adjustment and report on the effect on the polynomial and on the ozone retrievals from the DOAS algorithm. This would allow calculation of an estimate of how large calibration drifts would be needed to create the observed trends in differences. Information on the time dependence (or lack thereof) of the DOAS goodness of fit and number of iterations would be useful.

REPLY: Radiometric calibration errors can be additive or multiplicative. As mentioned by the referee, multiplicative errors are accounted for by the polynomial function fitted in the DOAS retrieval on the condition that such errors vary slowly with the wavelength. Hence, the simple experiment suggested by the referee has a negligible impact on the retrieved ozone column. In contrast, wavelength-dependent multiplicative errors and/or additive errors may have a substantial impact on the retrieved columns. If such calibration errors are time-dependent, a trend in the O_3 columns could possibly be observed. The m-factors have been developed to account for the instrumental degradation and will be applied in the next version of SGP. Their impact on the accuracy of the total O_3 product and in particular on its apparent trend will be investigated. No pertinent information can be drawn from the number of iterations, which are constant over time, nor from the residuals, which increase in a nominal way according to the known degradation of the satellite measurements.

I suggest to add at the end of page 264:

Possible time-dependent inaccuracies in the radiometric calibration procedure (leading to intensity offsets in the spectra) could be responsible for such a trend in the ozone columns. Indeed, the method is sensitive to additive errors and to wavelength-dependent multiplicative errors in this procedure.

COMMENT: The results for the comparison to the ground-based total ozone estimates show large variability in Figure 6. The individual stations in Figure 9 have different biases and gaps in their coverage. It is difficult to determine how these were combined to produce the single curve in Figure 6. One approach is to remove the individual station differences (each station's average bias) before combining them. There is no information in the bias of the combined result (This can be computed separately.) but the effects of data gaps would be reduced. While considerably more work, it would

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also be interesting to learn whether the other satellite data sets showed consistent differences in their overpass comparisons with the ground stations as expected from their differences with SGP 3.01.

Reply: Figure 6 was produced by averaging the SCIAMACHY/ground-based differences at each station without any further treatment or correction. As advised by the referee, we have recalculated the global monthly means after removal of the mean bias in the differences at each station. Although the variability is slightly reduced, the appearance of the new curve basically remains unchanged. For the sake of simplicity, we therefore propose to keep the original curve (based on original uncorrected ground-based measurements). The comparisons presented in this paper aim to verify the overall consistency of the SCIAMACHY/SGP 3.0 data set with correlative ground-based measurements, but are not meant as a full and comprehensive validation exercise. Adding comparisons of ground-based measurements with other satellite data sets would represent a large amount of work addressing the validation of these other satellite data sets. Such an endeavour is definitely beyond the scope of the present study. Moreover, dedicated papers deal with the validation of these different products.

Comment: The comparisons for the OMI record used the TOMS-heritage algorithm results. There is also a DOAS total ozone product from KNMI for the OMI. It may not be necessary to bring it in for direct comparison as there are existing comparisons of the two available. I will let the authors determine whether they are using the collection 2 or collection 3 OMI-TOMS data set and how the results in Slide 6 of Kroon, M.("Absolute quality of the EOS Aura Ozone Monitoring Instrument total ozone columns and vertical ozone profiles," EOS Aura 2008 Science Team Meeting http://avdc.gsfc.nasa.gov/index.php?site=1072744097validation) and in Figure 9 of Kroon, M., et al., (2008), would transfer to their comparisons. Depending on the data set used, there could be +-0.5 differences in the trend over the 2004-2008 time period between the OMITOMS and OMI-DOAS global records that would either intensify or diminish the reported OMI-SCIA differences.

Reply: The collection 3 of OMI-TOMS data have been used for the SCIAMACHY-OMI

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comparisons. The second reference provided by the referee shows that the differences between the OMI-TOMS and OMI-DOAS data (v1.0.5 collection 3) decrease from 0% in Oct. 04 to -1% in Apr 08. Consequently, comparisons between SCIAMACHY and OMI-DOAS would display a temporal trend slightly larger (-0.75%/year) than the one derived using OMI-TOMS data.

Changes in the manuscript:

Section 5.2 line 1: *...compared to the OMTO3 ozone columns (collection 3) derived from the OMI...*

End of section 5.2: ... -0.49%/year. Total ozone columns are also derived from the OMI spectra using another algorithm based on the DOAS technique (Veefkind et al., 2006). Recent comparisons (Kroon et al., 2008) have shown that the differences between the OMTO3 and the OMI-DOAS (v1.0.5; collection 3) columns, close to 0% in October 2004, gradually become more negative and reach about -1% in April 2008. Considering the OMI-DOAS instead of the OMTO3 columns for the SGP-OMI comparisons would consequently lead to a trend of larger amplitude.

References:

Veefkind, J.P., de Haan, J.F., Brinksma, E.J., Kroon, M., and Levelt, P.F.: Total ozone from the ozone monitoring instrument (OMI) using the DOAS technique, IEEE Trans. Geosci. Remote Sens., 44, 5, 1239 - 1244, doi:10.1109/TGRS.2006.871204, 2006.

Kroon, M., Veefkind, J.P., de Haan, J.F., McPeters, R.D., Bhartia, P.K., Balis, D., Petropavlovskikh, I., Froidevaux, L., Shetter, R., and Levelt, P.F.: Absolute quality of the EOS Aura Ozone Monitoring Instrument total ozone columns and vertical ozone profiles, presented at EOS Aura 2008 Science Team Meeting, available at: http://avdc.gsfc.nasa.gov/index.php?site=1072744097validation.

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Referee 2 (M. Weber)

COMMENT: Section 3.2, p. 258: This section on the appropriate wavelength shift and scaling of ozone cross-sections is inconsistent in terms of appropriate shifts for the GFM and SFM cross-sections. If the wavelength calibration of the solar reference spectrum is adjusted using the Fraunhofer line atlas, the optimized fitted shift values for the SFM and GFM cross-sections in the DOAS window 325-335 nm are cited as +0.020 and +0.028 nm, respectively. The recommended shift value of 0.02 nm for the SFM cross-section is used in the ESA retrieval (see Conclusion). Later the authors mention that the ESA retrieval for GOME uses a shift value of +0.016 nm for the GFM cross-sections (p. 259, line 15) and not the +0.028 nm as recommended here. Given a 2.5% error in retrieved columns per 0.01 nm shift, as the authors state, the GOME and SCIAMACHY results using the ESA retrievals should show a bias. This needs to be explained. The difference in shifts between SFM and GFM cross-sections of 0.008 nm found here is in agreement with results from Weber et al. (2007) from a direct comparison of the cross-section data including slit function adjustments.

REPLY: All pre-shift values quoted in this section have been derived using the respective O_3 cross-section data sets degraded at the SCIAMACHY resolution and aligned with respect to SCIAMACHY spectra based on test evaluations where the shift of the O_3 cross-section is allowed to vary as part of the DOAS fit procedure. Considering the GFM cross-sections, an optimal pre-shift of +0.028 nm has been derived based on fits to SCIAMACHY spectra. As noted by the referee, this value is different from the pre-shift determined using GOME spectra (+0.016 nm). The difference between the pre-shifts determined (in the same way) for each instrument probably originates from uncertainties on the absolute calibration of the GOME and SCIAMACHY spectra, possibly in relation with the known asymmetry of the GOME slit function in the 325-335 nm region (Van Roozendael et al., 2002). To clarify this point, I have added the following sentence at the end of section 3.2 and removed the corresponding sentence in section

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3.3:

For total ozone column retrievals from GOME spectra, the GOME data processor (GDP) version 4 uses the GFM cross-sections with a pre-shift of +0.016 nm (Van Roozendael et al., 2006). The difference with the pre-shift value determined in this work for SCIAMACHY probably originates from uncertainties on the absolute wavelength calibration of both instruments, possibly also related to the known asymmetry of the GOME slit function in the 325-335 nm region (Van Roozendael et al., 2002).

COMMENT: Figure 2: The authors do not discuss the red and green symbols in this figure. The red symbols are probably the shifts after Fraunhofer wavelength calibration (please state so in Figure caption), but the green symbols are neither explained in the figure caption nor discussed in the main text. Please do so. The shift values of around 0.008 nm indicated by the green symbols is consistent with the shift value for the GFM cross- sections in the ESA GOME retrieval (+0.016 nm), see discussion earlier.

REPLY: These symbols are explained in the caption of the figure itself. Nevertheless, this part of the text has been slightly modified as follows:

As can be seen, they are strongly dependent on the applied calibration procedure. Since the impact of a pre-shift error on the ozone column is important (about 2.5% per 0.01 n shift error), it is necessary to use a pre-shift properly adapted to the wavelength calibration scheme. The black symbols in Fig. 2 represent the pre-shifts derived using the original wavelength grid provided with level-1 data product. These values varying strongly from an orbit to another, it is clear that the default level-1 wavelength calibration is not stable enough, and that a fine-tuning of the wavelength registration is therefore required. In practice, this is performed by shifting the wavelength grid of the irradiance spectrum in the fitting interval (325.0-335.0 nm) until Fraunhofer lines are closely aligned with a reference atlas of solar lines (Chance and Spurr, 1997). This procedure, which is used as baseline for the total O_3 retrievals, leads to an optimal mean pre-shift of +0.020 nm for the SFM cross-sections (Fig. 2 - red symbols). A more complex wave-

length calibration procedure based on the shift of the wavelength grid in 4 consecutive micro-windows between 320 and 360 nm leads to a pre-shift of +0.008 nm (Fig. 2 - green symbols). The optimal mean pre-shifts derived using the simple wavelength calibration procedure for the other cross-section data sets are +0.011 nm, +0.028 nm and +0.035 nm for DM, GFM and BP, respectively. These values are consistent with the relative shift values displayed on Fig. 1 and also with the direct comparison of the GFM and SFM data sets realized by Weber et al. (2007).
Caption of Fig.2 :
O_3 cross-section pre-shift values determined from fits to a representative data set of 60 SCIAMACHY orbits, considering the impact of applying different wavelength calibration schemes (see text for a comprehensive description of the symbols).

COMMENT: p. 259, line 20-28. Here the authors show that after proper scaling and shifting of the SCIAMACHY ozone cross-section, an unexplained bias of 2% in the differences between SCIAMACHY and GOME remains. This is confirmed by using the same ozone cross-sections, here Bass-Paur (after convolution with instrument slit function of GOME and SCIAMACHY, respectively). Possible explanations are radiance calibration issues, but authors claim that exact causes are not known. In Weber et al. (2007), Figure 7, it was shown that the upgrade from V5 to V6 in the level-0-1 processing indeed causes such a 2% negative bias in retrieved total ozone. Also the fit rms increased with V6.
REPLY: In contrast to the results reported by the referee, comparisons for 60 orbits between SDOAS total ozone columns respectively retrieved from SCIAMACHY L1 v5 and L1 v6 files only display differences generally within the percent (positive and negative), with a slight SZA dependence. Due to this and for the sake of simplicity of this paper, we would prefer not to change this part of the text if the referee agrees. Note that the referee's paper is nevertheless cited in the section dealing with the pre-shifts of cross-sections.

COMMENT: Section 4: This section describes the hardware implementation of the

SGP 3 operational algorithm. It is far too technical and inappropriate here. This section should be shortened and mainly highlight differences in the settings of the SGP algorithm to that described for SDOAS in Section 2, if any, and briefly describe the calibration and retrieval steps.

REPLY: We suggest to remove section 4 and to add at the beginning of section 5:
Version 3 of the SCIAMACHY offline processor (SGP) represents a major upgrade (von Bargen et al., 2007). With a requirement to have an uninterrupted and fully consistent record of ozone data combining the GOME and SCIAMACHY measurements, one of the main goals of this SGP upgrade has been the incorporation of the SDOAS algorithm. In this version, measured radiances (Level 1b data v6) are first calibrated using the same algorithms as those implemented in the SciaL1C tool (Lichtenberg et al., 2006; Slijkhuis, 2005; Frerick von Bargen, 2007). As noted in section 2, the operational algorithm uses the OCRA/SACURA algorithm combination to derive cloud information.
In the present work, the SCIAMACHY SGP v.3.01 total O_3 *data product released in early 2008 has been evaluated using correlative satellite and ground-based data.*

MINOR ISSUES: The text has been modified to take into account all the comments raised by the referee.

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