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Interactive comment on "Validation of ENVISAT/SCIAMACHY columnar CO by FTIR profile retrievals at the Ground-Truthing Station Zugspitze" *by* R. Sussmann and M. Buchwitz

R. Sussmann and M. Buchwitz

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Final response to anonymous referee 1 by R. Sussmann and M. Buchwitz.

We like to thank the anonymous referee 1 for his efforts and appreciate all of his comments. Our point-to-point replies to the reviewers specific comments are presented thereafter.

Ad 1. "As mentioned above the main drawback is the limited data set of SCIAMACHY. In light of this I believe it is important to include a discussion what is known about the quality of the SCIAMACHY data from other sources instead referring to other papers. For instance the fact that the detectors of Schiamachy had some condensation prob-

lems and had to be heated periodically should be mentioned and what kind of data is included in the SCIAMACHY data set. This applies not only for CO but also O2, since this species is used in the validation."

We added several sentences to Section 3 describing more details on how the quality of the SCIAMACHY spectra affects the CO retrieval and also provide a short summary of the comparison with MOPITT, i.e.:

"In Buchwitz et al. (2005b) several days of SCIAMACHY global CO data over land have been compared with the operational level-2 CO column data product of MOPITT (ver. 3). It has been show that on average the difference between the two data sets is about 10 %. The largest differences have been found over the Southern Hemisphere outside Antarctica, where SCIAMACHY may overestimate MOPITT by up to about 30 % (over the Northern Hemisphere the agreement is much better). The standard deviation of the difference is in the range 0.4–0.6 10^{18} cm^{-2}, i.e., about 30 %. This standard deviation of 30 % is approximately equal to the expected single pixel retrieval precision of the SCIAMACHY CO columns. This holds for a restriction of the so-called retrieval error (see Buchwitz et al., 2004) to values below 60 %. A precision of about 10 % is the expected theoretical limit which, however, has not yet been reached mainly for two reasons: i) The currently used fitting window only covers a small subset of the CO lines detected by SCIAMACHY resulting in a random error due to instrument noise of about 20 % for an integration time of 0.5 s (Buchwitz and Burrows, 2004). For future versions of the retrieval algorithm we will aim at using a larger fitting window to improve the precision. ii) A quasi random error of about 5 – 20 % is introduced by disturbances due to variability of the atmosphere (e.g., aerosol scattering) and of the surface reflectivity not fully accounted for in the current version of the retrieval algorithm (Buchwitz and Burrows, 2004).

The CO retrieval from the SCIAMACHY spectra is complicated by an ice layer that grows on the (cooled) channel 8 detector. Every few month a decontamination procedure is performed to get rid of the ice layer. This ice layer not only affects the channel

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8 CO retrieval but also the channel 8 CH4 retrieval (see Buchwitz et al., 2005b). In Buchwitz et al. (2005b) it has been shown that the ice layer introduces a time dependent bias of the retrieved methane columns of up to about 15 % (low bias) as the ice layer changes the slit function of the SCIAMACHY spectrometer. A similar time dependent bias is expected for the SCIAMACHY channel 8 CO columns discussed in this paper. The SCIAMACHY O_2 columns are not affect by this issue (no ice layer has been observed for channel 4 used for O_2 retrieval)."

For the revised version of the paper we also added to Section 3 more details concerning the SCIAMACHY O_2 columns which have been used to normalise the CO columns, i.e.:

"Details on the O_2 retrievals are given in Buchwitz et al. (2005a). Several days of global SCIAMACHY data have been compared with O_2 columns computed from ECMWF surface pressures. It is shown that the mean difference of the daily data (SCIAMACHY-ECMWF) is on the order of one percent (between -2.1 % and +0.7 %) and that the standard deviation of the difference is about 10 % (between 7.9 % and 12.0 %). The standard deviation is believed to be dominated by quasi random retrieval errors introduced by the variability of the atmosphere (distribution of scatterers, temperature profile variations, etc.) and surface reflectivity variations not yet considered accurately enough in the retrieval algorithm (the random error due to instrument noise is well below 1 %). The estimated precision of the retrieved O_2 columns of about 10 % is large but significantly smaller than the variability of the CO columns and also significantly smaller than the O_2 column variability in areas of complex surface topography such as the Alps."

Ad 2. "In the comparison of the seasonal variation one single slope between March to Sep 2003 is compared, instead of comparing 3rd order polynomials, as used in Fig 1 for the FTIR data, why ?"

Obviously, the referee is referring to Figure 2 and not to Figure 1. We added the following explanation to the text (Section 4):

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"To investigate whether information on this annual cycle can also be retrieved from SCIAMACHY data in a statistically significant manner, a linear fit to both SCIAMACHY and FTIR data is performed for the time span for which SCIAMACHY data are available„ see Fig. 3. We used a linear fit as a proxy for the annual cycle because, contrary to the case of FTIR data (Fig. 2), a 3rd order polynomial fit turned out to yield no stable result for the SCIAMACHY data set. The reason for this is a combination of two effects, namely i) the SCIAMACHY data set does not cover one full period of the annual cycle (the FTIR data set does), and ii) SCIAMACHY data are showing a higher scatter than the FTIR data."

Ad 3. "In order to be able to get any significant slope in the SCIAMACHY data the amount of data points have to be augmented by increasing the radius for comparison up to 2000 km. The authors claim this is correct since it improved the scatter in the slope. For an absolute comparison this would certainly be problematic since the Zugspitze, from where the authors have conducted their column measurements, is situated above the mixing layer while Schimachy with a radius of 2000 km will pick up a lot of low polluted areas, such as the Po valley and Ruhr district. The authors are however studying the relative variability of CO (relative to pressure variations) and most of the seasonal variation will be the variation in the OH sink. However, it s not clear to men that part of the seasonal variation seen by Scimachy will also include the seasonal variation in combustion. The authors argue that a recent study by Yurganov, utilising solar FTIR measurements at many NDSC stations, is not showing a significant difference in the seasonal variation, but to my knowledge, very few or none of these stations are measuring in polluted areas."

The referee rises an interesting point and we therefore added the following discussion to the manuscript (Section 3):

"However, we note that the above mentioned clean-air-site sinusoidal CO annual cycle (Fig. 2) with a spring maximum and a fall minimum is due to the OH (sink) annual cycle. For clean-air sites this periodical behavior can be perturbed by long-range transport of

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CO from biomass burning events which usually accur during summer. As an example, there was an significant enhancement at all clean air sites in August 2003 all over the northern hemisphere due to boreal forest fires in the high northern hemisphere (Yurganov et al., 2004b). This can be seen in FTIR data of our Fig. 2. For polluted areas, like industrialized areas and towns there is another, periodical effect contributing to the total CO annual cycle. It is a contribution to the boundary layer due to heating and fuel burning with a mid-winter maximum and a mid-summer minimum, see, e.g., Bayerisches Landesamt für Umweltschutz (2005). This is directly linked to in the situ emissions without transport or chemical transformation processes being involved (i.e., a similar annual-cycle effect as observed for boundary layer NO_2).

The question is whether this third effect can become a dominant contribution to our SCIAMACHY data set including pollution hot spots within, e.g., a 2000-km selection radius around the Zugspitze (German Ruhr district, Italian Po valley), i.e., whether it should display a significantly different annual cycle compared to the clean-air site Zugspitze. We assume this not to be the case due to 3 reasons, namely i) the polluted areas are making up only a minor fraction of our 2000-km radius selection area, ii) a 2000-km radius selection area is only partially covered by SCIAMACHY pixels, and this fractional area is changing in magnitude and location, according to the availability of measurement orbits and nadir sequences, i.e., polluted areas are likely to be covered for some days and for some days not, and iii) the phases of the two periodical driving forces for the annual cycle are not very different (mid-winter versus spring maximum), see above. A quantitative independent answer to the relative magnitude of the two periodical contributions depending on selection area and columns ground altitude can not be given from measurements at the time being, keeping in mind that complementary satellite measurements by MOPITT do not show sensitivity to the boundary layer. However, for the limited number of SCIAMACHY data available for this study, we obtain evidence that increasing the selection radius for calculating daily means does support rather than hinder the goal of obtaining a well defined annual cycle comparable to that of the clean-air site Zugspitze, and helps to reduce the scatter of the satellite daily

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data, i.e., the relative winter time enhancement from pollution hot spots is negligible for sufficiently large selection radii (see results of Section 4 below)."

Ad 4. "The concept of using pressure normalized values for the FTIR and O2 normalized values for SCIAMACHY is interesting, since under the assumption that the profiles of the two species are similar, as pointed out by the authors, it will eliminate altitude variations of the measurements. On the other hand since the comparison is only relative to the mean value I have a problem to understand what it achieves in this case."

If the 2000-km selection radius would always be homogeneously covered by SCIAMACHY nadir pixels this normalization would be without any sense indeed. However, this is not the case. To make the consequence clear, we added the following explanation to Section 3:

"This normalization is to account for the fact that for each day there are SCIAMACHY data available only for part of the 2000-km radius selection area, and for changing locations, according to the limited availability of measurement orbits and nadir sequences for this individual day."

End of response.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 557, 2005.