

## ***Interactive comment on “Long-term analysis of carbon dioxide and methane column-averaged mole fractions retrieved from SCIAMACHY” by O. Schneising et al.***

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First of all we would like to thank the reviewer for the helpful comments. Below we give answers and clarifications to all comments made by the referee.

### **Minor Corrections and Comments**

*A very interesting result of this paper is the discussion of the Boreal forest uptake and the relative strengths of the Russian and North American regions. This should be*

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*mentioned in the abstract.*

A corresponding sentence will be added to the abstract.

*The “irregular sampling” of SCIAMACHY discussed in section 4.1 could be investigated by comparing with the seasonal cycles at various TCCON ground-based FTS stations. I recognise that the averaging kernel problem described in section 5 is a hindrance to direct comparison of the two measurements, but both SCIAMACHY and TCCON could be compared with CarbonTracker using the method employed in this paper.*

The “irregular sampling” mainly refers to the fact that there are no retrievals available passing the quality filter for high latitudes during winter, so that the yearly mean is rather a summer mean in this region. This cannot be further investigated by comparing with TCCON ground-based FTS stations. In general, a comparison with FTS stations is a very relevant point but is out of scope of this paper. This will be done in the near future.

*P27480, line 21. It would be nice to have the errors listed for all important numbers mentioned in the text. (For example, the annual mean increase (1.8 +/- X ppm/yr and 1.9 +/- X ppm/yr).)*

This will be added in the revised version.

*P27485, line 15. Does your O2-A band spectroscopic forward model include the effects of line-mixing? If not, how much of a difference is this likely to make? Does the “Change of full width at half maximum (FWHM) used for the O2 reference spectra calculation ...” described a few points lower down compensate for line mixing or some other spectroscopic bias? What is the effect of changing the widths on the retrieved O2?*

The forward model does not include the effects of line mixing. As line mixing is not implemented in the used radiative transfer model the influence on the retrieval results cannot be estimated by simply comparing the results derived with and without line

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mixing. Due to the fact that small constant offsets of the retrieved XCO<sub>2</sub> are less critical when used for inverse modelling of surface fluxes, only the variability (e.g., with SZA) of the potential error is important. Interpreting the results of Tran et al. (2008) for retrievals from atmospheric measurements for purely Voigt line shapes in this sense, the line mixing issue may be estimated to be on the order of less than 0.5% for typical air mass factors.

The change of FWHM seems to compensate partially for line mixing or other spectroscopic biases because the fits get systematically better when changing the FWHM from 0.45 nm to 0.44 nm. The effect on the O<sub>2</sub> is a reduction of the retrieved column amount by about 0.5%.

*P27485, lines 12-13. How do the M-factors change over time and how do they affect the Xco<sub>2</sub> growth rate and seasonal cycle (if they do)?*

The temporal evolution of the M-factors can be seen on <http://www.iup.uni-bremen.de/sciamachy/mfactors/plots.html> for all SCIAMACHY channels and light paths. Without the application of the M-factors the retrieved XCO<sub>2</sub> growth rate would be two to three tenths of 1 ppm smaller. The seasonal cycle amplitude of the northern hemisphere is not affected by the M-factors, whereas the amplitude in the southern hemisphere is about 0.3 ppm/yr smaller when compensating for the radiometric degradation of the instrument. The growth rate and seasonal cycle results with M-factor degradation correction are in better agreement with CarbonTracker.

*P27486, section 3.2. Why do you normalize CH<sub>4</sub> with CO<sub>2</sub> instead of with O<sub>2</sub>? How do the results compare when you normalize CH<sub>4</sub> by O<sub>2</sub>?*

In contrast to carbon dioxide the WFM-DOAS data product of column-averaged methane dry air mole fractions uses simultaneously retrieved CO<sub>2</sub> instead of O<sub>2</sub> as a proxy for the air column because of better cancellation of path length related retrieval errors. This is due to the neighbouring fitting windows of CO<sub>2</sub> and CH<sub>4</sub>, whereas the O<sub>2</sub> A band is spectrally distant. Normalisation of CH<sub>4</sub> by O<sub>2</sub> instead of CO<sub>2</sub> potentially

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leads to larger path length related retrieval errors, in particular in the presence of sub-visual cirrus clouds (see discussion in the carbon dioxide section). This will be briefly mentioned in the revised version.

*P27487, lines 20-22. Why do you require the same number of retrievals for each of the three periods, instead of requiring the same quality of the retrievals? Could you please explain this further?*

When processing the same ground scene (before November 2005) with the pixel mask after October 2005 and the pixel mask for the prior time period, respectively, the methane fit error gets on average about three times worse with the 200511+ pixel mask. Therefore the filter criterion after October 2005 on the methane fit error is relaxed correspondingly to approximately maintain all measurements that would also pass the quality filter if the earlier pixel mask could still be used. This is important to obtain a consistent time series with similar sampling before and after the pixel mask change. Additionally, there would be no good measurements left (or only very few) after October 2005 without relaxation of the filter criterion on the CH<sub>4</sub> column fit error. In contrast to that, the filter criterion on the RMS of the fit residuum is not changed.

*P27489, lines 10-11. To what do you attribute the 0.3% bias between SCIAMACHY and CarbonTracker? This is very small compared with the GOSAT bias, which is on the order of 2% (see Morino, I. et al., Atmos. Meas. Tech. Discuss., 3, 5613-5643, doi:10.5194/amtd-3-5613-2010, 2010). Is this related to changing the widths of the O<sub>2</sub> spectroscopy?*

There are many factors that can introduce small biases of the retrieved XCO<sub>2</sub> including line mixing, errors of the spectroscopic data, the choice of standard CO<sub>2</sub> and aerosol profiles, and also the change of the full width at half maximum (FWHM) used for the reference spectra calculation. The attribution to a single cause is probably not possible, it is rather a combination of many causes.

*P27489, lines 19-20. I'm not sure you can claim that the annual increases between*

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*CarbonTracker and SCIAMACHY are different, since they all agree within error (according to Table 1). It seems from Table 1 that the largest differences are seen in the annual increases in the 30S-30N region, where SCIA and CT just barely agree within error. Further discussion/investigation of this point might be interesting.*

This formulation is a relict of earlier results without M-factor degradation correction when the differences of the annual increases to CarbonTracker were a few tenths of 1 ppm larger. This will be reformulated in the revised version.

*P27492, lines 17-20. Please elaborate on the statement: "Due to the fact that the prevailing wind direction in mid- to high-latitudes is from west to east, one would expect a negative west-to-east longitudinal gradient for the considered region because the air masses are mainly moving according to this wind direction over the uptake region." This seems like an interesting approach, but it is not discussed fully enough.*

This will be explained in more detail in the revised version.

*P27493, first paragraph. This is an interesting result. It would be good to mention whether any other paper has noted this phenomenon. Could the difference between CarbonTracker and SCIAMACHY be due to a timing error (phase lag) in the onset of the forest uptake in CASA, such as that described in Keppel-Aleks et al. (Atmos. Chem. Phys. Discuss., 10, 30569-30611, doi:10.5194/acpd-10-30569-2010, 2010)? Why do you average over May through August? What do the results look like when averaging over shorter time periods (say, only July and August)?*

To our knowledge this phenomenon has not been noted explicitly in this form so far. The results of Keppel-Aleks et al. suggest that different flux strengths and timings of the seasonal cycle introduce differences in corresponding gradients. Therefore, a potential regional timing error in the onset of the forest uptake in the CASA model might contribute to the observed difference between CarbonTracker and SCIAMACHY. We average over May through August because this is the period between the maximum and minimum of the seasonal cycle. Actually, the restriction to shorter time periods

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starting later (e.g., June–August) reduces the differences between CarbonTracker and SCIAMACHY concerning the relative strengths of the Russian and North American regions to some extent. However, the qualitative findings remain the same. A brief discussion of this issue and a citation of Keppel-Aleks et al. will be added in the revised version.

*Figure 1. It would be useful to include in the caption that the shaded regions indicate "bad" pixels, and that the last remaining usable (not "serviceable") pixel is located at 896 (if that is correct, of course).*

Will be included.

*Figure 2. Could you show the error bars on the Global Mean bar graph? (The same question applies to Figure 10.)*

As the global means are averages over all measurements within the corresponding year (order of magnitude is about  $10^6$ ), the standard error of the mean is very small (about 0.01 ppm for XCO<sub>2</sub> and 0.04 ppb for XCH<sub>4</sub> before 2006 and 0.07 ppb since 2006). These values have been confirmed using a bootstrapping technique. Therefore, error bars are omitted for these figures because they would not be visible in the graph. We will mention the errors in the figure caption instead.

*Figure 9. Middle panel. Are the shaded regions the data themselves? What are the solid red and black lines? Are they the linear combinations? It would be useful to have these described in the caption.*

The shaded regions show the standard deviations of the zonal XCO<sub>2</sub> averages and the solid lines the fitted linear combinations. The figure caption will be revised accordingly.

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## Technical Corrections

All technical corrections will be considered in the revised version of the manuscript.

## References

Tran, H., and J.-M. Hartmann (2008), An improved O<sub>2</sub> A band absorption model and its consequences for retrievals of photon paths and surface pressures, *J. Geophys. Res.*, 113, D18104, doi:10.1029/2008JD010011.

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Interactive comment on *Atmos. Chem. Phys. Discuss.*, 10, 27479, 2010.