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Atmospheric Measurement Techniques Discussions

Interactive comment on "Validation of six years of SCIAMACHY carbon monoxide observations using MOZAIC CO profile measurements" *by* A. T. J. de Laat et al.

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— Referee #2 (Leonid Yurganov) —

We would like to thank the referee for his useful comments. See below for our reply, and the supplementary information for the modified paper (changes highlighted).

1: justification & goal of the paper)

(note: we deal with issues regarding averaging kernels, aerosols and clouds below)

First of all, the referee makes an important observation at the end of this review when

he writes that "Validation of satellite sensors at source areas is necessary because these data are used for top-down estimates of emissions. If a sensor is not sensitive to the boundary layer, then estimates obtained from the data are not accurate. The paper includes MOSAIC data for such areas and this is an advantage of the paper."

We included this important observation to the end of the introduction as it provides a justification for the validation of our CO data using MOZAIC.

The referee makes valid points regarding NIR vs. TIR CO measurements from satellites, however, we nevertheless respectfully disagree with the notion that the "usefulness of the paper is limited."

First of all, the goal of this paper is not to demonstrate the advantages of NIR compared to TIR. The issue of NIR vs. TIR was addressed in a previous paper [de Laat et al., 2010a], where we compared SCIAMACHY NIR with MOPITT TIR CO. In that paper we clearly identified differences between CO total columns from both instruments and also found biases in IR CO (later acknowledged by IASI , see George et al. [2009]). Although not specifically discussed, results from de Laat et al. [2010b] also indicate where and when NIR provides information that TIR cannot provide.

Furthermore, SCIAMACHY was the first instrument to demonstrate the possibility of retrieving valuable CO information from NIR measurements. However, due to instrumental issues the signal-to-noise of SCIAMACHY NIR CO is low, but until recently there was no other instrument available measuring CO at NIR wavelengths (MOPITT NIR has changed that to some extent).

A first validation of IMLM CO was presented in de Laat et al. [2010b], using ground based FTIR measurements, and although results indicated a reasonable quantitative agreement, that study was hampered by the relatively few FTIR locations as well as several complications related to the FTIR locations (mountains, islands etc.).

The MOZAIC data provides a crucial extension of the results, as noted by de Laat et al. [2010b] as there are more measurement locations available and include regions not covered by the FTIR network. However, as discussed in the conclusions, results from this study confirm the findings of de Laat et al. [2010b], thus showing that despite SCIAMACHY instrumental issues valuable information on CO can be retrieved from NIR measurements, which bodes well for the future with the upcoming instrument TROPOMI.

In summary, the goal of the paper, i.e. investigating the quality of SCIAMACHY CO measurements, is justified regardless of the availability of CO measurements from other instruments and measured at other wavelengths. The goal of this paper is not to investigate the merits of NIR over TIR CO (which was recently addressed in Worden et al. [2010]).

2: Averaging kernels, clouds and aerosol effects)

There are relatively few truly collocated SCIAMACHY and MOZAIC measurements due to various issues like clouds and the spatio-temporal coverage of SCIAMACHY and MOZAIC. As explained in the paper, it is required to average SCIAMACHY measurements both in space and time in order to reduce instrument-noise error levels – which are large [see further Gloudemans et al. [2008, 2009]; de laat et al. [2007, 2010a, 2010b]. As a result, a meaningful direct comparison between SCIAMACHY and MOZAIC profiles is not possible. Application of the SCIAMACHY averaging kernels in the traditional "Rodgers" type of way thus cannot be performed. We agree that this would be quite problematic for measurements that show a considerable altitude variation of sensitivity, like the thermal infrared CO measurements [de Laat et al., 2010a].

However, and fortunately, the SCIAmachy NIR CO measurements are close to uniformly sensitive to the vertical [Gloudemans et al., 2008]. In de Laat et al. [2010a] it was shown that for one year of model simulated daily CO profiles from around the globe – thus covering a wide range of tropospheric CO profile shapes - effects of the

averaging kernels were (much) less than 10%. Note that 10% has been established as the precision of SCIAMACHY measurements due to uncertainties in absorption spectra and radiative transfer calculations, as discussed in the paper. By this workaround we argue that the averaging kernel effects can - to first order - be ignored, as explained in de Laat et al., [2010a].

The validation results – as also discussed in de Laat et al. [2010b] for the validation using ground-based FTIR measurements – are therefore dominated by other factors like instrument-noise errors and representativeness of the spatio-temporal SCIAMACHY averages.

It should also be kept in mind that the MOZAIC profile is not a true profile but a slant profile due to the landings and departures tracks of the commercial aircraft – is probably representative for a much larger area than suggested by the fact that it is a profile.

The effect of clouds has also previously been estimated, and depends on whether measurements are performed over land or over oceans. Over oceans, we include measurements over low altitude clouds (surface to 800 hPa), as outlined in Gloudemans et al., [2009]. Over land, we only use measurements for scenes with a cloud fraction of 20% or less. Note that the cloud fraction measurements we use in most cases overestimates cloud amounts, and the tests with different cloud covers fractions did not reveal a systematic dependence of results on cloud cover fractions < 20% [de Laat et al., 2007]. This was not clearly described in the paper and we have added this now in section 2.1.

Furthermore, effects of (thin) aerosol layers have been estimated to be small [de Laat et al. [2007].

We extended the discussion of SCIAMACHY averaging kernels briefly, but for the main discussion we refer to Gloudemans et al. [2009] and de Laat et al. [2010a].

A brief discussion of cloud and aerosol effects – including references above – was added to the paper.

Contrary to what the referee suggests, the discrepancies between SCIAMACHY CO and MOZAIC CO for locations #11, 21, and 24 are not the result of the AK, as averaging kernel effects can only explain differences of a few percent. The observed differences however result from mainly very local pollution as observed by MOZAIC versus the rather large spatial averaging needed for SCIAMACHY.

Comparison with model results for Beijing and Teheran lead to similar results: MOZAIC CO total columns are much larger than modeled. Furthermore, de Laat et al. [2010b] presented a comparison with ground based stations in Japan, showing excellent agreement and only very small statistically insignificant biases. Given the close proximity of Japan to the Beijing area, whatever causes the large CO total columns thus cannot be a large scale phenomenon, otherwise it would have shown up in the comparison with the Japan stations. In addition, comparison between SCIAMACHY IMLM CO and MOPITT IR CO in de Laat et al. [2010a] also does not reveal differences over the Beijing and Teheran area (10-40%) as large as seen here (100-400%), and we note de Laat et al. [2010a] included the effect of the MOPITT and SCIAMACHY averaging kernels on the comparison between both.

For Lagos, Nigeria, model results indicate that larger CO columns do occur when using a smaller area for comparison, showing that here the CO columns are a regional phenomenon. Thus, for Lagos the choice of the 8x8 degree comparison area is most likely the cause of the differences.

So, the CO total columns for Lagos, Teheran and Bejing are dominated by regional or local process, which justifies why we also calculated statistics excluding these stations.

We also added a brief discussion on these discrepancies in the revised manuscript in section 3.1.

Page 1988)

We added the following to section 2.1:

“The retrieval method described here is based on an Iterative Maximum Likelihood Method (IMLM). The forward model includes the atmospheric absorption and the instrument characteristics. The IMLM algorithm fits a model of the expected detector signal to the measurements by varying the total amounts of the trace gases that play a role in the selected retrieval window. For more algorithm details we refer to Gloudemans et al. [2008, 2009].”

Page 1991, lines 8-12)

The text has been modified for clarity.

“For more than 95% (99%) of the CO profiles this subcolumn contributes less than 20% (30%) of the total column.. Considering that TM5 model biases in upper atmospheric CO are not larger than 10-20% [Huijnen et al., 2010], biases in the total columns for the combination of MOZAIC and TM5 data that can be attributed to biases in TM5 cannot be larger than a few percent.“

Page 1997)

(see also our answer above under 2:Averaging kernels, clouds and aerosol effects)

De Laat et al. [2010a] discussed SCIAMACHY NIR CO averaging kernel effects. It was noted in section 3.1 that, when applying SCIAMACHY NIR CO averaging kernels to one year of daily chemistry-transport model CO profiles that:

“Applying the SCIAMACHY CO total column averaging kernel results in a slightly larger CO total column of 4 ± 4 % or $0.04 \pm 0.04 \times 1018$ molecules/cm2 for solar zenith angles of 25° to 0.4 ± 0.1% or $0.005 \pm 0.001 \times 1018$ molecules/cm2 for solar zenith angles of 80° compared to those without applying the total column averaging kernel.”

Thus, CO total column differences due to the SCIAMACHY CO averaging kernels under a whole range of realistic CO profile shapes are not larger than 8% (at the 95%

confidence level), and most likely smaller as most solar zenith angles for SCIAMACHY measurements are larger than 25°.

The kernel shape of NIR CO shows little vertical variations, so that large effects of the kernels is simply not possible (see figure 2 of de Laat et al., [2010a]).

For the explanation of the 'local effects' see above and our detailed response to referee#1, and the text changes to section 3.1.

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Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/5/C1141/2012/amtd-5-C1141-2012-supplement.pdf

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