

Interactive comment on “Shipborne solar absorption measurements of CO₂, CH₄, N₂O and CO and comparison with SCIAMACHY WFM-DOAS retrievals” by T. Warneke et al.

T. Warneke et al.

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We would like to thank D. Griffith for reviewing the manuscript. In the following a short response is given to each of his comments.

Reviewer: “P850, line 3: should this read an accuracy (not precision) of 0.5%?”

Authors Response: Precision is correct. Yang et al. (2002) showed that the diurnal variation of the CO₂ column is less than 0.5% and used the diurnal variation as a measure of precision. We adopted this measure of precision in this work.

Reviewer: “Shipborne solar measurements Using a column averaged mixing ratio to

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compare with in situ measurements (as is done later in the paper) is strictly only correct if the vertical mixing ratio profile is uniform. For CO₂ this is reasonable, but for CH₄ it is problematic because of the fall-off in the stratosphere. Waschenfelder et al made a correction for this using co-retrievals of HF to allow for the effect of stratospheric reduction. Did the authors also do this? If yes, it should be explicitly mentioned, if not, the consequences for comparison with CMDL in situ and SCIAMACHY DOAS measurements should be discussed.”

Authors Response: We did not correct the methane column for its stratospheric part for 3 reasons:

a) We used a different detector and a different beamsplitter than Washenfelder et al.. For this reason the spectral region that contains HF absorption lines is not covered in the spectra which we use for the retrieval of CH₄, CO₂ and O₂. b) The SCIAMACHY DOAS retrievals are not corrected for the stratospheric CH₄ and the main objective of the paper is the comparison with these data. c) Waschenfelder et al. assumed a linear CH₄-HF relationship in the stratosphere to obtain the tropospheric CH₄ column. This linear CH₄-HF relationship varies with latitude (Luo, M., R. J. Cicerone, and J. M. Russell III, Analysis of Halogen Occultation Experiment HF versus CH₄ correlation plots: Chemistry and transport implications, J. Geophys. Res., 100(D7), 13,927-13,937, 1995). In contrast to Washenfelder et al. we would have to assume different CH₄-HF slopes for different positions of the ship, which is likely to introduce systematic errors.

As mentioned by the reviewer a comparison with in situ measurements is only correct if the vertical mixing ratio profile is uniform. An additional uncertainty for the comparison of the FTIR data and the CMDL data arises from spatial distance between the CMDL stations and the ships position. Despite these problems we use this data because to our knowledge the CDML data is the only available dataset suitable for a comparison in this work. In the revised manuscript we will point out these problems.

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Reviewer: “Diurnal variations. I would prefer to see a plot of all the FTIR data as a function of time, to see for myself the actual variability and diurnal variation (or lack of it), instead of the current figure 1, which shows only the scatter with any real signal removed. The diurnal scatter statistics can be simply quoted in the text. The authors take an implicit assumption that there is no real diurnal variation, and that whatever variation is seen is due only to the measurement. This assumption may be valid, but it should be explicitly justified. What about the effects of biomass burning plumes? How do these affect short term (< 1 day) variations? (If Fig 1 is replaced with a plot vs. time, we the readers could see this for ourselves.)”

Authors Response: We followed Yang et al. (2002) and used the diurnal variation as a measure of precision. This gives a worst case precision because it includes real variations over the day. The reason for using it anyhow is the difficulty to find a meaningful measure of precision for the presented remote sensing measurements. One future possibility would be the use of the variation of the column averaged vmr of O₂, which is (to the degree required) constant. However, currently the data contains systematic errors which partly cancel in the CO₂/ O₂ ratio.

The diurnal variation has been established as a measure of precision (at least for the column averaged vmr of CO₂) and we would like to keep figure 1, because this makes the precision of these shipborne data comparable with earlier work, especially with the first work about ground based measurements by Yang et al. (2002).

We agree that the real scatter should be visible for the reader. Therefore we will replace the daily means presented in figure 3 by the individual measurements.

Reviewer: “Comparison with CMDL in situ data: The biases between CMDL and FTIR data are 4-10% for CO₂ and CH₄. The ATMOS/HITRAN line parameters are probably accurate to better than 1-2% for strengths, maybe a little worse for widths, so it is not sufficient to assign all the disagreement to the line parameters. Instrument bias (such as imperfect ILS) and retrieval bias must also play some part in the observed biases.”

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Authors Response: If we would use the surface pressure instead of the O₂ column to calculate the column averaged volume mixing ratio the bias would be ~2-3 % for CO₂ and ~3-6 % for CH₄. Hence the retrieved O₂ adds a large part to the observed bias. If the surface pressure is used to calculate the column averaged vmr the scatter is larger. For this reason we decided to use the O₂.

Our assumption that the bias is due to the solar and spectral linelists is based on the following:

a) From the comparison of FTIR - CO₂ data obtained by different instruments at different sites (Spitsbergen, ship data) with model data we concluded that the instrumental bias is less than 1%. b) We observed that the scaling factor for the column averaged vmr is very sensitive to the used spectral and solar linelists.

We agree that the source of the bias is not completely clear and will state this in the revised manuscript.

Reviewer: "Why is there no comparison with CMDL CO and N₂O data?"

Authors Response: The focus of the paper is the comparison with the SCIAMACHY-DOAS data. Available data from SCIAMACHY DOAS retrievals are: a) total columns (molecules/cm²) for CO, N₂O, CO₂ and CH₄ b) column averaged volume mixing ratios for CO₂ and CH₄. Due to the cancellation of systematic errors the column averaged mixing ratios are more precise than the total columns and are therefore used for the comparison of CO₂ and CH₄.

SCIAMACHY and FTIR data of N₂O and CO would have to be converted to VMRs to compare it to CMDL data. However, we did not want to modify the SCIAMACHY-DOAS but use the products that are available from SCIAMACHY-DOAS retrievals and not modify them.

Reviewer: "4. Comparison of shipborne... P854 line 20: "The deviation between DOAS and shipborne data is less than 4% at these latitudes." Is this after the scaling of FTIR

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data to match CMDL, or before?”

Authors Response: This is after scaling the FTIR data. We will add this to the revised manuscript.

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