Atmos. Chem. Phys. Discuss., 6, S5089–S5092, 2006
www.atmos-chem-phys-discuss.net/6/S5089/2006/

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Interactive comment on “Simultaneous ground-based observations of O_3, HCl, N_2O, and CH_4 over Toronto, Canada by three Fourier transform spectrometers with different resolutions” *by* D. Wunch et al.

Anonymous Referee #2

Received and published: 6 December 2006

This paper describes simultaneous analyses of solar FTIR absorption spectra using a common optical beam path through the atmosphere but three different spectrometers of different designs and resolutions. The study provides a useful analysis of factors which affect the accuracy and consistency of retrievals of atmospheric trace gas distributions from solar absorption spectra, and as such is of value and benefit to the NDACC and other remote sensing communities. The paper is suitable for publication in ACP, but only after revision of some of the text to make the results and conclusions of the study clearer and more useful to readers. In particular section 3 requires a

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substantial rewrite.

Section 3 - SFIT2 and “forward model” description. The description/definition of “forward model” is confusing and inconsistent The term refers to FSCATM on p 5, but to something quite different in 3.1 on the next page. FSCATM is only part of the forward model - it is the algorithm used to calculate the ray path through the atmosphere, based on assumed pressure-temperature-concentration profiles and the solar zenith angle. The “forward model” is the procedure used to calculated the observable quantity - in this case the IR absorption spectrum - from an assumed set of input parameters. This includes not only the calculated ray path from FSCTM, but also the layered spectrum calculation, which is based on Hitran line parameters. SFIT2 is the “inverse model”, which calculates the most probable set of input parameters to the forward model (including trace gas concentrations and ILS parameters) which would lead to a given observed spectrum.

Section 3 - resolution, lineshape and profile retrieval. It is not clear exactly how SFIT2 is being implemented with respect to total column retrieval vs vertical profile retrieval and ILS retrieval, and this needs to be spelled out clearly. This is important because the observed lineshapes in measured spectra are determined by both the ILS and the assumed (a priori) vertical profile, and there is significant correlation between the two effects. I am not sure from the text if the vertical profile is retrieved in ALL cases as part of the SFIT2 retrieval, even when only the total column is reported. But there is an important difference between retrieving the total column with profile retrieval and column retrieval with the profile fixed at the a priori. If the profile is fitted, how realistic is it to also fit ILS parameters (6 of them) from the same spectrum? Is there enough information in the spectra (especially for narrow stratospheric lines and/or lower resolutions where there are only a few data points to define each measured lineshape)? The use of a separate window to fit ILS parameters in the PARIS instrument (3.1, p7 column 1) is also related to this issue - how much did the ILS retrievals vary over a day, and what is the author’s definition of “success” in fitting the ILS from the same or different

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windows. All these effects question the validity of the approach, and solid justification is needed.

The results of 3.3 suggest that fixing the ILS parameters at the LINEFIT values, and retrieving them from the spectra do give similar results, but are the profiles fitted in the exercise of 3.3? It isn't clear. (By the way, which spectrum/spectra were used in 3.3? The text does not say, but the caption to Fig 8 implies spectra of 2 Sept.)

The "spurious oscillations in the profile" observed for CH4 may well be due to overfitting rather than lineshape parameters errors if both ILS and profile are being fitted and the inversion is under determined. Both N2O and CH4 show systematic residuals in the fitted lineshapes regardless of the ILS fitting method used, which suggests that the vertical profile is wrong. With so many free parameters to fit the observed lineshape, the residuals should be better than this.

Overall, the presentation of this issue of lineshape and resolution effects (which is the core of the paper!) is unclear - resolution is treated in 3.2 with simulated spectra, while LINEFIT vs PHS/EAP is treated separately in 3.3 from measured spectra. It seems obvious to take the measured TAO spectra in 3.3 and reduce their resolution to those of the other two instruments and examine the effects. Was this done? It may do away with the need for 3.2 altogether. So in summary, I would like to see 3.2 and 3.3 re-worked into a more coherent presentation.

4. Results The comments about tracker errors for zenith angles less than 40 degrees need justification. Generally tracker errors are more critical at low sun angles where the airmass is a stronger function of sza.

Methane errors may be due to assumed vertical profile rather than line parameters errors - see above discussion

5. Conclusions Given comments on 3.2 and 3.3 above, I am not convinced that the final conclusion is true - ie that using SFIT2 to retrieve ILS parameters as part of the

state space can be used in place of an independent determination, eg with LINEFIT. Desirable it may be, but requires better justification.

Further points Sect. 3, p5 “Every attempt was made to ensure the TAO FTS incurred a minimal loss of signal ...”. Was this realized? Is the beam from the solar tracker so large that the beams for the other two instruments could be picked off the side without blocking the main beam? If so, what is the impact on the effective solar viewing angle for the two beams which view only the edge of the solar beam?

P5. “The only difference between the three retrieval methods ...”. There is only one retrieval method, but 3 cases, maybe “cases” should replace “methods”.

3.1. Why did the authors not use a consistent version of LINEFIT to fit the ILS of the three instruments. Is there any risk of systematic differences due to LINEFIT algorithm changes between versions?

Section 3. last sentence before 3.1. .”... the bulk of the discrepancies can now be attributed to differences in instrument resolution.” I suggest add “ ... and instrument lineshapes” since these clearly also play a large part.

P7 col 1 ." ...from a very broad N2O band ...” should read “N2O line”

Apart from the suggestions for 3.2 and 3.3 above, theses sections could be substantially shortened, in that the text largely duplicates what is clear from the figures and is repetitive.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 10883, 2006.