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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Measuring atmospheric CO_2 from space using Full Spectral Initiation (FSI) WFM-DOAS" *by* M. P. Barkley et al.

M. P. Barkley et al.

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Referee 2

The authors would like thank referee 2 for taking the time to read this manuscript and provide his/her useful comments and suggestions on this work.

We have amended all figures and captions, plus performed all the technical corrections as requested.

Abstract, lines 14-19:

The errors on the retrieved CO_2 columns can be reduced by using a priori data within the retrieval i.e. so that a better linearization point for each WFM-DOAS fit is chosen.

However, we agree the retrieved CO_2 does depend somewhat on *a priori* data used.

For example, if a sub-arctic temperature and water vapour profiles are used to perform global retrievals then a bias will certainly be introduced.

If sensible *a priori* information is included in the retrieval algorithm then this does not bias the retrieved CO_2 columns.

Abstract Line 15:

We accept the referee's comment and have adjusted this sentence to:

"Hence, a more flexible implementation of the WFM-DOAS retrieval technique, called Full Spectral Initiation (FSI) WFM-DOAS, has been developed..."

Abstract Line 17:

Changed to: " ...the estimated properties of the atmosphere and surface..."

Abstract Line 21:

It is unlikely that the 'significant' spatial features observed over Siberia are entirely due to measurement error, especially as the observations been averaged over a month. However, we acknowledge that this is difficult to clarify so accordingly we have changed this sentence to:

"...they also contain interesting spatial features."

Page 2768 line 21:

We have removed the two references: O'Brien and Rayner (2002) and Kuang et al. (2002) and replaced them with those suggested by the referee.

Page 2769 lines 1-3:

We have replaced the paragraph:

"Observations of CO_2 (Houweling et al., 2005), carbon monoxide (CO) (Frankenberg et al., (2005) and Buchwitz et al., (2004)) and methane (CH_4) (Frankenberg et al.,

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2005) have been performed. From these studies, a global CO_2 data set for 2003 has been prepared by Buchwitz et al. (2005), using a relatively new retrieval algorithm called *Weighting Function Modified Differential Optical Absorption Spectroscopy* (WFM-DOAS)."

with:

" SCIAMACHY CO_2 retrievals have been performed initially by Buchwitz et al. (2005), using a relatively new retrieval algorithm called Weighting Function Modified Differential Optical Absorption Spectroscopy (WFM-DOAS) and also by Houweling et al. (2005) using the Iterative maximum Likelihood Method (IMLM), (Schrijver,1999)."

Page 2771 1st paragraph.

The temperature profile is scaled, not shifted. This has been changed accordingly.

Page 2773 line 3 and following:

The US temperature profile was used in the simulations described in subsection 3.2, hence we have added to line 2:

"...and used in conjunction with the US Standard temperature and water vapour profiles."

A reference to the CO_2 climatology has been added. See response to referee 1.

The shape of a CO_2 profile at a given location will not be known exactly however, over a set latitude range a mean profile can give a reasonable representation of the vertical CO_2 distribution. More information on the observed shape of CO_2 profiles is given in the two cited references Anderson et al. (1996) and Nakazawa et al. (1997).

Page 2773 subsection 3.3

It should be noted that the error analysis performed here uses a different (smaller) spectral fitting window to that used in the study of Buchwitz and Burrows (2004), thus

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one has to be careful about a direct comparison. However, we have added (to line 2, page 2774):

"These results are consistent to those presented in Buchwitz and Burrows (2004)"

The extra information for the ECMWF profiles has been included in the revised table.

Title of subsection 3.4 has been changed to:

"Sensitivity to the combined effect of using alternative CO_2, H_2O and temperature vertical profiles"

Page 2775, subsection 3.5

We have added to the end of this section the sentence:

"The magnitude of this error is almost identical to that found by Buchwitz et al., (2005), (see their Figure 1)."

Page 2771 line 11 and following

Many simulated retrievals were performed using such height resolved weighting functions examining the effects of the CO_2, H_2O and temperature vertical profiles, the surface elevation and surface albedo on the retrieval. We also tested CO_2 perturbations at different altitudes. We also tried fitting height resolved derivatives for just CO_2 whilst keeping column scaling factors for water vapour and temperature.

In some instances, using this method did increase the sensitivity of the WFM-DOAS algorithm. However, the results were very inconsistent, varying very much on the scenario implemented in the simulation. From our efforts we find it very difficult to draw any conclusions regarding this issue. Accordingly we have included this sentence within this section to explain this:

“In some instances, using this approach did increase the sensitivity of the WFM-DOAS algorithm. However, the results from these simulations were very inconsistent, varying

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very much on the scenario implemented in each synthetic retrieval. As a result, it is difficult to draw any conclusions regarding this alternative method."

Page 2778 line 3 and following

See response to referee 1.

Page 2779 line 15 and following:

The authors acknowledge that within the FSI algorithm aerosols are only dealt with very simply (and are welcome to any suggestions to overcome this difficulty).

We add the sentence (Page 2779, line21) to acknowledge this:

"This representation of the local aerosol conditions however, is still quite limited."

However, we believe that using a three background aerosol scenarios is clearly better than using a global maritime background as in Buchwitz et al. (2005). For example, the test scenes illustrated in the paper (Fig. 14) are of the Siberian region, over which the aerosols will originate from terrestrial rather than maritime sources.

The urban aerosol scenario is only implemented when a city has a population of greater than 75,000 people (i.e. large built up areas where the aerosol loading is expected to be greater). How can using maritime aerosols be more appropriate in such instances?

It should also be noted that the FSI algorithm also selects the corresponding season and relative humidity which are implemented in the LOWTRAN aerosol model (which are not taken into account in Buchwitz et al. (2005)).

Page 2780 line 6:

This sentence is misleading and has been removed.

We have added at the end of this section:

"All columns are normalized to the ECMWF surface pressure to produce a column volume mixing ratio (VMR)."

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We have also inserted into section 5 (page2780, line21):

"...accepted (column VMRs lying outside this range are likely to originate from undetected clouds or from aerosol scattering)."

Figs 11 and 13.

This may be a question of semantics. We do not accept that we have forced the correlations to be high. We simply discard the CO_2 retrievals which either (a) have errors greater than 5% or (b) do not fall within the accepted range quoted within the paper (i.e. which acts, in essence, as a secondary cloud filter). Observations which fall into either category we classify as failed retrievals. As these values are not used in any plots or analyses, why should they be included in the correlation?

Fig 12:

We have added the solar zenith angle as requested. We explain how the *a priori* surface albedo is estimated in section 4 (page 2779, lines 10-15).

Section 4 general and comments regarding Fig 14

The referee has commented that we have:

"...performed an error analysis for FSI-WFM-DOAS in comparison to the look up table implementation of Buchwitz et al. (2005) (let us call this LUT-WFM-DOAS)."

This is not strictly true. We have assessed the accuracy of WFM-DOAS for various simulated atmospheric and surface conditions. From this analysis we only conclude that the calculation of a reference spectra for each SCIAMACHY observation must reduce the error on each retrieved CO_2 column.

We have not compared FSI-WFM-DOAS directly to LUT-WFM-DOAS, as both retrievals use SCIAMACHY spectra that have been calibrated differently and FSI-WFM-DOAS does not (currently) normalize with oxygen (as the LUT-WFM-DOAS algorithm does). May be this could be the goal of future research efforts? In this paper we have only

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concentrated on possible biases from the *a priori* data.

In a forthcoming ACPD paper we have compared our results to independent ground based FTIR data and the output from the TM3 chemistry transport model. This work gives an indication of how well the algorithm is performing. Estimates of the accuracy and bias of the FSI algorithm are also given in this paper (Barkley et al., ACPD, submitted, 2006).

We have indicated this within the text of section 5 (page 2780, lines 23-24) by adding a reference to this future paper:

"In this initial analysis, comparisons to chemical transport models, for example the TM3 model (Heimann and Korner, 2003) or ground station data are not made, as such data will be used in future research to determine the precision and accuracy of the FSI algorithm (Barkley et al., 2006)."

We therefore do not think that it is necessary to include a comparison figure of CO_2 columns derived using the LUT-WFM-DOAS algorithm (as the reader has the option to seek out such plots in the cited references), nor do we believe a table summarizing the error sources needs to be added.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 2765, 2006.