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Interactive Comment

## Interactive comment on "Measuring atmospheric CO<sub>2</sub> 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 1

We would like to thank the referee for his useful and insightful comments regarding this work.

All the typographic errors have been corrected.

Specific comments:

Page 2768, lines 7-12:

Sabine et al. (2004) citation added for the carbon budget.

Page 2771, line 11:

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Only a uniform temperature shift for the whole profile was considered. We do not know the effect of using derivatives based on different climatologies.

Page 2772, equation 2:

The notation of equation 2 has been changed.

Page 2772, line 25:

A reference to the  $CO_2$  climatology has been added. The preparation of this data base may be the core of a future paper, which is outside the scope of this current work.

Page 2773, 2nd paragraph:

Inclusion of an *a priori*  $CO_2$  profile within the FSI algorithm, improves the linearization point for each retrieval, as it represents the atmosphere more realistically than assuming a uniform distribution. (It is also not time consuming to implement.)

The instruments sensitivity is not taken into account in this comparison as an averaging kernel correction is not always possible when comparing SCIAMACHY  $CO_2$  to other independent data, whether that be from ground based FTIR, model output (that does not have profile information) or from other satellites.

If the averaging kernel correction can be applied, as in some retrieval-model comparisons, then the difference is smaller, typically tenths of a percent. However if it cannot, then there will be a bias between the true  $CO_2$  and that retrieved by SCIAMACHY which is why an *a priori*  $CO_2$  vertical profile is important.

Page: 2773-2774, section 3.3:

Table 2 has been amended.

The authors acknowledge that water vapour is highly variable in the atmosphere which is why an ECMWF water vapour profile is used within the FSI algorithm, as this best represents the prevailing local conditions rather than using some climatological mean 6, S991–S995, 2006

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profile.

If only a mean water vapour profile, is used then iterations are likely to be necessary.

The FSI spectral fitting window does contain (relatively) weak  $H_2O$  absorption lines, from which the  $H_2O$  total column can be derived. However  $H_2O$  total columns are not presented as a useable product since the errors associated with the retrieved  $H_2O$  columns are much larger than those associated with the CO<sub>2</sub> (usually from 25% to 100% for  $H_2O$  as opposed to typically less than 5% for CO<sub>2</sub>). It is not sensible to incorporate the retrieved  $H_2O$  vertical column back into the algorithm as we have little confidence in it. The same can be said for the retrieved temperature scaling factor.

The error created by not performing any iteration (to adjust for the water vapour variability) is small i.e. significantly less than 1% (but this is difficult to quantify exactly).

We do acknowledge however, that this is not clear within the text therefore we have changed the sentence (page 2778, line 4)

"Were this not an issue, then the retrieved  $CO_2$  vertical column density would be fed back into the algorithm iteratively."

Page 2775, section 3.6:

The authors acknowledge that the error analysis performed with respect to the surface albedo is very simple and assumes no interference from aerosols. This is not clear in the text hence we have added to the end of this section:

"The errors increase further still at very low albedos. This simple test, which doesn't account for the coupling between the surface reflectance and aerosols (Houweling et al., 2005), demonstrates that employing a fixed albedo within the algorithm, will introduce what are essentially unnecessary errors."

Section 3.7:

Yes, aerosols can increase the photon path length thus we have corrected this by

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adding:

"Aerosol scattering can either shorten the photon path-length leading to an underestimation of the  $CO_2$  column or alternatively, if the high surface albedo is high, can also increase the optical path length causing an overestimation (Houweling et al., 2005)."

Page 2776, line 18:

We don't know why the errors increase when the temperature weighting function is included.

Section 3.8:

Our mistake, we interpreted the IMAP-DOAS approach incorrectly. We have removed this sentence and instead added (to help answer referee 2 comments as well):

"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 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 16:

This has been changed to:

The number of fitting points within this micro-window is usually thirty-two, with each detector pixel spanning a wavelength interval of 0.7 nm. Owing to the broad slit function of this channel (see Sect. 5), SCIAMACHY does not fully resolve the  $CO_2$  absorption bands.

Page 2782, line 25:

Using  $O_2$  as a proxy is a far from ideal. Thus a sentence has been added:

"However, fundamental differences between the radiative transfer and the averaging kernels of the respective  $CO_2$  and  $O_2$  spectral fitting regions suggests that a proxy,

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derived from an wavelength interval closer to the 1.57  $\mu\text{m}$  CO $_2$  band, would be more beneficial."

Page 2791, table 2:

There is no evidence of a correlation between the error and surface temperature.

Page 2791, table 3:

It is not our intention to perform an exhaustive aerosol error analysis as the limited simulations shown in Table 3 clearly show just how important aerosols are. Nevertheless we have added the sentence in section 3.7:

"For other surface albedos (other than the default of 0.2) these errors will be different (e.g. Houweling et al. (2005))."

Page 2800, figure 7:

We agree that the errors do depend on the aerosols present, however from these simple albedo simulations we only want to give the reader the two key points which are (1) at very low albedos the errors increase dramatically and (2) for higher values this error should be typically within 2% or so (assuming background aerosol conditions).

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