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Atmospheric Chemistry and Physics Discussions

Interactive comment on "First direct observation of the atmospheric CO_2 year-to-year increase from space" *by* M. Buchwitz et al.

M. Buchwitz et al.

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Author's answers to interactive comments of anonymous Referee number 2 on paper Buchwitz et al., First direct observation of the atmospheric CO_2 year-to-year increase from space, Atmos. Chem. Phys. Discuss., 7, 6719–6735, 2007

First of all we would like to thank the referee for her/his constructive comments. Below we give answers to all comments made by the referee. Each comment will be carefully considered for the revised version of the manuscript.

Answers to: Major comments:

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Answer to major comment 1:

The referee is probably right that the annual CO_2 increase can (at present) be determined better using the ground-based network because these measurements are very precise and accurate and because most of the sites have been carefully selected to be representative for background conditions. On the other hand, surface measurements can only detect what happens at the surface and assumptions concerning vertical mixing are required to estimate how the total atmospheric CO_2 amount (or the average mixing ratio) increases from one year to the next. Similar remarks apply to the seasonal cycle as recently shown in Yang et al., GRL, 2007. The study of Yang et al. has shown that using current transport models to infer seasonal changes in northern hemispheric CO_2 mass from surface measurements of the CO_2 mixing ratio results in significantly too low net ecosystem exchange (NEE), due to too week vertical mixing in the transport models. The findings from Yang et al. stem from the analysis of FTS and (extrapolated) aircraft based measurements of the column-averaged dry molar mixing ratio of CO_2, denoted XCO_2 in our paper. The Yang et al. paper demonstrates the usefulness of column-averaged CO_2, i.e. XCO_2, measurements, and points to limitations when interpreting the surface measurements.

The usefulness of the satellite XCO_2 in terms of increasing our knowledge about the carbon cycle requires that it can be demonstrated that a certain data quality in terms of precision and accuracy has been achieved. A reliable error estimate is however extremely challenging (see below). The main strength/goal of the satellite data is to provide additional information on the regional scale, i.e., the regional scale is the scale where the potential to increase our knowledge about the carbon cycle using satellite XCO_2 is largest, as no other measurements with global coverage exist. Our paper focuses on large scale CO_2 features, not on regional pattern (this aspect will

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be discussed in the cited Schneising et al., 2007, paper which is under preparation). To what extent the satellite retrieved large scale features, such as the seasonal cycle and the annual increase discussed in this paper, are useful in terms of increasing our knowledge about the carbon cycle still needs to be assessed. The conclusions drawn in the Yang et al. paper stem from one to a few ppm differences, which is on the order of the estimated error of the satellite data. Therefore the answer to the question of the usefulness of large scale averages is not straight forward. The main focus of our paper is to show that it is possible to observe the CO_2 year-to-year increase from space and that it is possible to observe changes on the order of a few ppm using satellite data. This can be interpreted as an encouraging result but based on this it is not straight forward to assess to what extent this data set may increases our knowledge about the carbon cycle. Probably one of the best approaches to assess this is to investigate the consistency of the satellite retrievals with the available surface, aircraft and FTS XCO_2 measurements, i.e., using an approach similar as has been used by Bergamaschi et al., JGR, 2007, for SCIAMACHY methane retrievals. This probably also requires, if possible, to take uncertainties in the vertical mixing of the transport model(s) into account. Such an assessment is however out of the scope of the present paper.

The 1 ppm/year error estimate comes primarily from the comparison with the CarbonTracker reference data and not from the error analysis. We think that the systematic error of the differences between yearly averages is very difficult to quantify reliably using an error analysis because this requires assumptions concerning to what extent errors cancel/reduce when averaging XCO_2 retrievals corresponding to a large range of conditions and how the disturbing parameters change from one year to the next. As such an error estimate can hardly be obtained without introducing major assumptions we used the comparison with the independent CarbonTracker data set to estimate this error. We will adjust the revised version of the paper to make this more clear.

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Answer to major comment 2:

The referee points out that the error analysis suffers from the fact that not all error sources, in particular errors related to aerosols, residual clouds and spectroscopy, have been included appropriately in the discussion. We agree with this and will add more details concerning these and other error sources for the revised version of the paper. Because we were aware that a reliable error analysis taking into account all possible error sources is hardly possible, we included a second independent approach to estimate the error on the seasonal cycle by analyzing the difference with respect to CarbonTracker over the southern hemisphere where the seasonal cycle is supposed to have a significantly smaller amplitude compared to the northern hemisphere. This approach is however also based on several assumptions and therefore has clear limitations as correctly pointed out by the referee.

Because of the difficulties in performing a reliable error analysis for the highly averaged data shown in this paper we will use a different approach for the revised version of the paper which does not rely on many critical assumptions. We will discuss several error sources and quantify them as good as possible but we will not aim at a full error analysis. Instead we will use the difference to CarbonTracker as a (conservative) estimate of our (systematic) error of the amplitude of the seasonal cycle and the observed year-to-year increase. This difference is a conservative estimate of the SCIAMACHY error as it also includes the error of CarbonTracker (this requires that the CarbonTracker errors are not significantly positively correlated with the SCIAMACHY errors which is very likely a good assumption).

Information on the accuracy of CarbonTracker will be added for the revised version of the paper.

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Interactive Comment

Answers to: Minor comments:

p.6720, line 25:
The name of a surface network will be added.

p.6721, line 10:
"Synthetic" will be added.

p.6721, lines 10-15:
"Near-infrared" will be added.

p.6721, line 27 and following:
The new results on biases published in Chevallier et al., JGR, 2007, will be considered for the revised version of the paper.

p.6722, line 2:
Not only the spectral range is similar, also one of the viewing geometries (nadir), etc. Nevertheless, there are significant differences and we will change the corresponding sentence. The part starting with "... which will perform similar ..." will be replaced by "... which will also perform nadir observations in the near-infrared spectral region but optimized for CO_2 in terms of, e.g., better spectral and spatial resolution." or equivalent.

p.6724, line 4 and following:
The referee is right that the polynomial is the better for e.g. aerosol correction, the more optically thin the spectral region is. We will take this into account for the revised version of the paper.

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p.6724, line 16 and following:
The referee is right that an error is introduced if, for example, a fixed CO_2 profile shape is used for the retrieval (in Section 5 this error is estimated using simulated retrievals). In this sense the retrieval depends on a priori assumptions. Our main point is that the output of the satellite retrieval, namely the retrieved CO_2 seasonal cycle and the retrieved CO_2 increase, is information that has not been provided to the retrieval algorithm on input by any means. Will will adjust the paper taking this comment into account.

p.6725, line 15 and following:
The referee is right that the oxygen column retrieval can distinguish between cloudy and cloud free scenes independently if the surface is covered by snow and/or ice or not. At present we do not take advantage of this. Will will add some sentences to the revised version of the paper to provide more details about this.

p.6726, line 15 and following:
As will be shown in the cited Schneising et al., 2007, paper, the SCIAMACHY XCO_2 has a low bias of approximately 1% compared to two northern mid latitude FTS stations (Park Falls, Wisconsin, USA and Bremen, Germany). We also found that the SCIAMACHY data are about 1% lower than CarbonTracker (for the northern hemisphere and the southern hemisphere). Therefore the SCIAMACHY XCO_2 is probably too low by about 1%. Because of this, the SCIAMACHY XCO_2 shown in Fig. 1 has been scaled with 1.01 to correct for this. The data shown in Fig. 2 have not been scaled. For Fig. 2 a scaling factor close to 1.0 would not result in any significant changes as the data are shown as anomalies, i.e., mean values have been subtracted.

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Figure 1 and 2:
The referee is right that there are data gaps. The data gaps arise because of our filtering. The purpose of the filtering is to reject low quality retrievals. This means that the gaps cannot be filled with high quality data (at least not without a significantly improved retrieval algorithm). Filling the gaps with low quality data would introduce a bias. If one wants to use the SCIAMACHY data to estimate CO_2 source/sink strength for example, then the sampling has to be considered. For the paper the most relevant figure is Fig. 2 because most of the conclusions are drawn from Fig. 2. In Fig. 2 we compare the SCIAMACHY retrievals with CarbonTracker sampled as SCIAMACHY measures, i.e., taking the gaps into account when comparing SCIAMACHY with CarbonTracker. We will add for the revised version of the paper that there are data gaps and that this has implications, for example, that the northern hemispheric averages, shown in Fig 1., are not true northern hemispheric averages but suffer from imperfect sampling to some extent. This will be explained in the revised version of the paper.

Answers to: Technical comments:

All technical comments will be considered for the revised version of the paper.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 6719, 2007.