METHANE AND CARBON DIOXIDE COLUMN-AVERAGED MIXING RATIOS FROM SCIAMACHY ON ENVISAT

O. Schneising, M. Buchwitz, M. Reuter, H. Bovensmann, and J. P. Burrows

University of Bremen FB1, Institute of Environmental Physics (IUP), Otto-Hahn-Allee 1, 28359 Bremen, Germany, E-mail: Oliver.Schneising@iup.physik.uni-bremen.de

ABSTRACT

Methane (CH_4) and carbon dioxide (CO_2) are the two most important anthropogenic greenhouse gases contributing to global climate change. Despite their importance our knowledge about their variable natural and anthropogenic sources and sinks has significant gaps. Satellite observations can add important global scale information on greenhouse gas sources and sinks provided the data are accurate and precise enough and are sensitive to the lowest atmospheric layers where the variability due to regional greenhouse gas sources and sinks are largest. SCIAMACHY onboard ENVISAT is the first satellite instrument which covers important absorption bands of both gases in the near-infrared/shortwave-infrared (NIR/SWIR) spectral region. In nadir mode SCIAMACHY observes reflected and backscattered solar radiation. The daytime measurements are therefore very sensitive to near-surface greenhouse gas concentration changes except in case of significant cloud cover. At the Institute of Environmental Physics (IUP) of the University of Bremen, Germany, the Weighting Function Modified Differential Optical Absorption Spectroscopy (WFM-DOAS or WFMD) algorithm has been developed and is continuously being improved to extract the atmospheric greenhouse gas information from the SCIAMACHY spectra. Retrieval and analysis focussed on the first three full years of the ENVISAT mission (2003-2005) but recently we started to also analyse the data after 2005. The status of this ongoing retrieval activity will be presented including first results from analysing SCIAMACHY data after 2005.

1. INTRODUCTION

The carbon gases carbon dioxide (CO_2) and methane (CH_4) are the two most important anthropogenic greenhouse gases and contribute to global warming. The reliable prediction of future atmospheric greenhouse gas levels and the associated global climate change requires an adequate understanding of their sources and sinks and their spatiotemporal distribution. Unfortunately, the current knowledge of the carbon surface fluxes is limited for example by the sparseness of the ground-based network and uncertainties are large (see, e.g., Stephens et al. [11]). Theoretical studies have shown that satellite measurements in combination with models have the potential to significantly reduce these surface flux uncertainties if they are accurate and precise enough [5, 8].

The near-infrared nadir spectra of reflected solar radiation measured by SCIAMACHY onboard ENVISAT [1] contain information on the vertical columns of these gases which we retrieve using the scientific algorithm WFM-DOAS [2, 9, 10] and which are converted to column-averaged mixing ratios, denoted by XCO_2 or XCH_4, respectively, by normalisation with the air column.

The existing data set WFMDv1.0 [9, 10] is based on Level 1 calibration version 5 (L1v5) and covers the time period 2003-2005. To process data after 2005 the usage of L1v6 is required. Other changes with the corresponding WFMDv1.2 developed for this purpose (aside from the Level 1 version update) compared to WFMDv1.0 are: (i) Update of methane and water vapour spectroscopy in the methane fitting window according to Frankenberg et al. [3] and Jenouvrier et al. [6], (ii) extended look-up table covering additional ground height 5km and additional albedos 0.6 and 1.0, (iii) modified static pixel masks to ensure sufficiently good fit quality until 2009, (iv) CarbonTracker release 2008 instead of release 2007 [7] for correcting the methane data, (v) SCIAMACHY Absorbing Aerosol Index [12] instead of EarthProbe/TOMS AAI for filtering out strong aerosol contaminated ground scenes, in particular desert dust storms.

A prerequisite for retrievals after 2005 using L1v6 is a consistency assessment reprocessing selected data from the time period 2003-2005 and comparing them with the current WFM-DOAS data products in order to find out if the retrieval results are similar. Since first indications of detector degradation in SCIAMACHY channel 6+ have been found for the methane retrieval in 2005 [10], an analysis of the stability of the instrument is also important to determine the quality of the SCIAMACHY greenhouse gas retrievals after 2005. First results of this consistency and stability analysis are summarised in the following section.

2. RESULTS

A first step to assess the consistency of the new version of WFM-DOAS, WFMDv1.2, which has been optimised to process L1v6 spectra until 2009 and WFMDv1.0 for the overlapping time period, is the comparison of the data quality for single orbits. Fig. 1 exemplarily shows such a comparison of the corresponding data sets without quality filtering for an orbit in late 2003. As can be seen, both versions give similar results concerning column-averaged mixing ratios as a consequence of similar retrieved vertical columns. The fit quality is also comparable or better for the updated version WFMDv1.2.

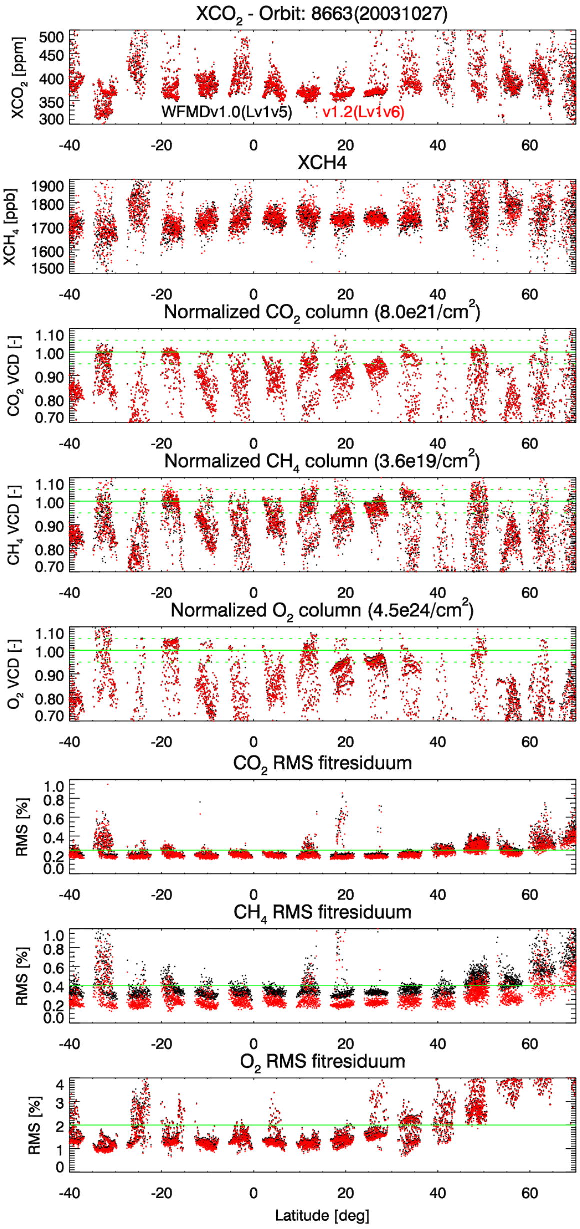

Figure 1. Comparison of WFMDv1.0 as applied to L1v5 (black) with WFMDv1.2 as applied to L1v6 (red). As can be seen, a similar or better data quality has been achieved.

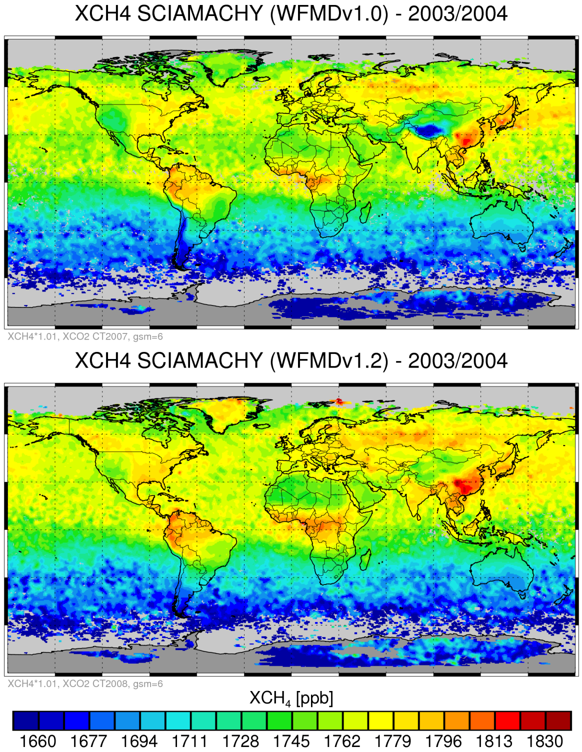

Figure 2. Comparison of 2-year averages of WFMDv1.0 and WFMDv1.2 quality filtered XCH_4.

The analysis of larger time periods is illustrated in Figs. 2 and 3 showing global 2-year averages of quality filtered retrievals of XCO_2 and XCH_4, respectively, covering the years 2003 and 2004 and revealing quite similar results for WFMDv1.0 and WFMDv1.2 which demonstrates the consistency of the two data sets. However, exactly identical retrieved patterns cannot be expected because the sampling is slightly different, for example due to the switch to the SCIAMACHY Absorbing Aerosol Index or differences in the number of available SCIAMACHY spectra for the different calibration versions. Furthermore, the look-up table improvements for high latitude and high reflective scenes necessarily lead to deliberate deviations in these cases. For instance, the low bias over high mountains, e.g., the Himalaya Range, compared to model simulations for WFMDv1.0 XCH_4 disappears in the WFMDv1.2 methane data set.

It has to be pointed out, as already mentioned in the introduction, that the WFMDv1.2 data sets are optimised for the time period 2003-2009 by choosing static pixel masks which ensure sufficiently good fit quality for the entire time. Hence, the shown WFMDv1.2 2-year-means are most likely not of the best theoretically achievable quality for 2003-2004 because, compared to a data set optimised for this shorter time period, more detector pixels are excluded as a consequence of the static pixel mask approach, namely pixels that turn dead or bad afterwards. This is in particular true for the methane retrievals with a distinct increase of dead or bad pixels with time in the corresponding spectral region. For example,

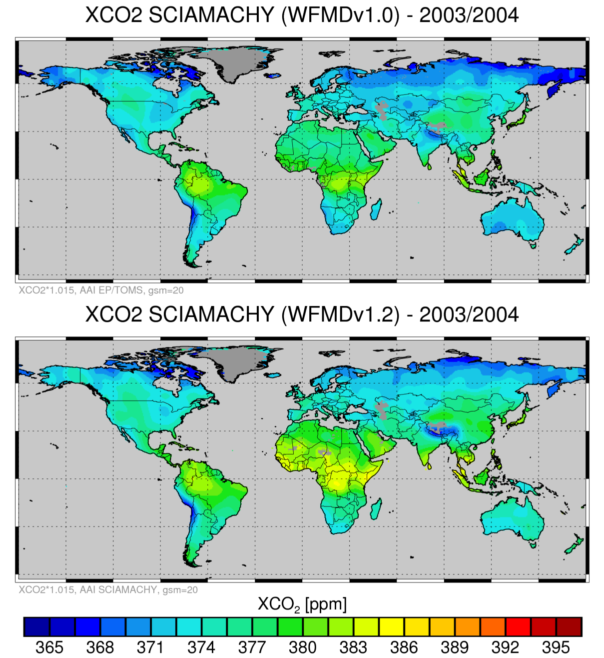

Figure 3. Comparison of 2-year averages of WFMDv1.0 and WFMDv1.2 quality filtered XCO_2.

the tropical methane enhancement of WFMDv1.0 (optimised for 2003-2005) which decreased after update of water vapour spectroscopy (WFMDv1.1) [10] in consistency with Frankenberg et al. [4] and in better agreement with model simulations is now increasing again because of the updated stricter pixel mask being valid for a longer time period. Thus, the retrieved tropical enhancement depends on both used spectroscopy and pixel mask.

The previous analysis has shown that we can produce a consistent data set beyond 2005. In this context it is important to examine if the SCIAMACHY results are stable with time or begin to suffer from detector degradation in the spectral regions used for the greenhouse gas retrievals. Fig. 4 shows the WFMDv1.2 XCO_2 retrieval results for the northern hemisphere based on monthly data demonstrating the stability after 2005. Clearly visible is the seasonal cycle and the CO_2 increase with time for the whole considered multi-year time period.

Unlike carbon dioxide, some potential degradation problems for methane have already been identified for WFMDv1.0 2005 data [10]. For the updated version WFMDv1.2 with a modified stricter pixel mask to ensure sufficiently good fit quality until 2009 and improved calibration there is no obvious degradation for CH_4 until end of October 2005 but significant lower quality afterwards concerning considerable larger scatter as well as the introduction of systematic biases starting November 2005.

This worsening is directly connected to essential detector pixels going bad in channel 6+ which is used for the methane retrieval. The main information in the used $2\nu_3$ methane band comes from the Q-branch where the ab-

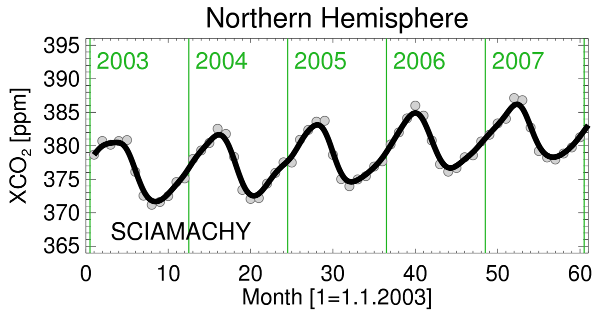

Figure 4. First XCO_2 results from processing SCIAMACHY data after 2005 for the northern hemisphere using WFM-DOAS. As can be seen, the SCIAMACHY CO_2 retrieval is very stable also after 2005.

sorption is strongest. As the Q-branch ranges only over four SCIAMACHY detector pixels, dead or bad pixels in this interval have adverse consequences for the retrieval. In the WFMDv1.2 pixel mask the pixel with the second strongest absorption is already excluded because it turns bad beginning of 2005. The detector pixel with the strongest absorption turns bad beginning of November 2005 leading to the described worsening of the methane retrievals (while still allowing sufficiently good fit quality). However, this pixel is not excluded because this would significantly reduce the retrieval quality for the previous time period when using a static pixel mask which is favourable in principle because a dynamic pixel mask might introduce additional artificial variability. Additionally, with the exclusion of the two strongest pixels of the Q-branch it can most likely not be expected to meet the accuracy and precision requirements to be useful for inverse modelling anymore. The situation is getting even worse beginning 2007 when the third of the four pixels covering the Q-branch turns bad.

Therefore one has to decide for future methane retrievals if it would be better to use a dynamic pixel mask despite the fundamental potential drawbacks or a pixel mask optimised for 2003 - Oct 2005 to get the best results possible for this time period. Another question one has to answer in this context, in particular for retrievals after 2006, is, how meaningful a retrieval from the $2\nu_3$ methane band can actually be with only few or at worst no available information from the Q-branch.

3. SUMMARY

It was shown that is possible to obtain CO_2 and CH_4 data sets using improved L1v6 calibration being consistent with retrievals based on previous calibration which is important because the usage of L1v6 is required to process data after 2005. First results from analysing SCIAMACHY data after 2005 show very stable results and no signs of degradation for CO_2. However, in the spectral region used for the CH_4 retrieval an increasing number of dead or bad pixels with time complicates the retrieval and stability with the current pixel mask is only assured until end of October 2005. The reason is the degradation in early November 2005 of the detector pixel with the strongest absorption of the Q-branch of the $2\nu_3$ methane band where the main methane column information comes from. Therefore, it is doubtful that the accuracy and precision requirements for methane to be useful for inverse modelling can be met anymore when excluding this detector pixel supplementary.

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