CARBON MONOXIDE, METHANE AND CARBON DIOXIDE RETRIEVED FROM SCIAMACHY NEAR-INFRARED NADIR OBSERVATIONS USING WFM-DOAS

M. Buchwitz 1), R. de Beek 1), J. P. Burrows 1), H. Bovensmann 1), B. Dils 2), and M. De Mazière 2)

1) Institute of Environmental Physics (iup) / Institute of Remote Sensing (ife), University of Bremen FB1, Otto Hahn Allee 1, 28334 Bremen, Germany, E-mail: Michael.Buchwitz@iup.physik.uni-bremen.de
2) Belgian Institute for Space Aeronomy (BIRA-IASB), 3, Avenue Circulaire, 1180, Brussels, Belgium

ABSTRACT

The three “carbon gases” carbon monoxide (CO), methane (CH₄) and carbon dioxide (CO₂) are important atmospheric constituents affecting air quality and climate. The near-infrared nadir spectra of reflected solar radiation measured by SCIAMACHY on-board ENVISAT contain information on the vertical columns of these gases which we retrieve using the scientific algorithm WFM-DOAS. For CH₄ and CO₂ our main data products are dry air column averaged mixing ratios (XCH₄ in ppbv and XCO₂ in ppmv) determined by simultaneous measurements of the dry air mass obtained from oxygen (O₂) for CO₂ and O₂ for methane. Our CO data product is the CO vertical column in molecules/cm². The SCIAMACHY data set is unique because of the high sensitivity of the near-infrared measurements with respect to concentration changes in the atmospheric boundary layer. This sensitivity is a prerequisite to get information on regional surface sources and sinks which are currently only poorly constrained globally by atmospheric measurements. We present a short overview about the latest versions of the retrieval algorithm (WFM-DOAS version 0.5 for CO and CH₄ and version 0.4 for CO₂) and processed data (year 2003 data set based on Level 1 version 4 spectra) including comparisons with global and local reference data (MOPITT, ground based FTS, and global models).

1. INTRODUCTION

Carbon monoxide (CO) is an important air pollutant affecting local air quality and carbon dioxide (CO₂) and methane (CH₄) are the two most important anthropogenic greenhouse gases and contribute to global climate change. The near-infrared nadir spectra of reflected solar radiation measured by SCIAMACHY [1] on-board ENVISAT contain information on the vertical columns of these gases which we retrieve using the scientific algorithm WFM-DOAS [2-6,8]. Here we present the latest results for CO and methane obtained with version 0.5 of the WFM-DOAS retrieval method [6,8]. The CO₂ results have been obtained with WFM-DOAS version 0.4 [4-6,8]. This v0.5 CO and methane and v0.4 CO₂ data set has recently been compared with a network of ground based FTS measurements [9]. A few days of v0.4 CO₂ data has also been compared earlier with ship-based FTS measurements [11]. Here we present a short summary of the current status of this activity.

2. TRACE GAS RESULTS

We have processed all available SCIAMACHY Level 1 version 4 spectra of the year 2003 [6,8]. Because of the low reflectivity of water (oceans, great lakes) in the near-infrared the quality of the measurements over water is typically reduced and only measurements over land are discussed here.

2.1 Carbon monoxide (CO)

Carbon monoxide columns are retrieved from a small spectral fitting window located in SCIAMACHY channel 8. The latest version of the retrieval algorithm is WFM-DOAS version 0.5 [6,8]. Figure 1 shows a comparison of SCIAMACHY CO with the operational CO column data product of MOPITT [7]. On average the SCIAMACHY CO columns are higher by about 10% but regionally, especially over South America, the differences can be much larger. More details are given in [6,8]. Fig. 4 shows an overview about the comparison with ground based FTS measurements (11 NDSC stations). As can be seen, the differences between WFM-DOAS version 0.5 CO and ground based FTS over the northern hemisphere are typically less than 10%. Over the southern hemisphere differences are typically around 20%. More details are given in Tab. 1 and [9].
2.2 Methane (CH₄)

Methane dry air column averaged mixing ratios are retrieved from a small spectral fitting window located in SCIAMACHY channel 6 [6,8]. CO₂ from channel 6 is used as a proxy for the light path and the CO₂ column is used to estimate the air column necessary to compute a methane column averaged mixing ratio (see also [10]). The latest version of the retrieval algorithm is WFM-DOAS version 0.5 [6,8]. Figure 2 shows SCIAMACHY v0.5 methane over various source regions. Fig. 4 shows an overview about the comparison with ground based FTS measurements (11 NDSC stations). As can be seen, the differences between WFM-DOAS version 0.5 methane and ground based FTS are within about 2% (standard deviation). More details are given in Tab. 1 and [9].
Fig. 2: Methane column averaged mixing ratios as retrieved from SCIAMACHY using WFM-DOAS version 0.5 globally (a) and for various regions (b-f). The SCIAMACHY measurements are solar zenith angle bias corrected (see [6]) and scaled with 1.02.
2.3 Carbon dioxide (CO$_2$)

CO$_2$ dry air column averaged mixing ratios are retrieved from a small spectral fitting window located in SCIAMACHY channel 6 [4,5,6,8]. O$_2$ from channel 4 is used as a proxy for the light path and the O$_2$ column is used to estimate the air column necessary to compute a CO$_2$ column averaged mixing ratio. The latest version of the retrieval algorithm is WFM-DOAS version 0.4 [4,5,6,8]. Fig. 3 shows a comparison with global model simulations. Tab. 1 summarizes the results of the comparison with FTS. Note that only a few stations measure column averaged CO$_2$. The comparison with the FTS is based on three non-ideal stations (Jungfraujoch: mountain station not observing the boundary layer; Ny Alesund: high latitude stations (low sun, low snow/ice albedo), and Egbert (strong influence of local sources)). More details are given in [9].

**Fig. 3:** Top: Carbon dioxide column averaged mixing ratios as retrieved from SCIAMACHY using WFM-DOAS version 0.4. Bottom: Corresponding TM3 model simulations (courtesy S. Körner and M. Heimann, MPI-Biogeochemistry, Jena, Germany). The SCIAMACHY averaging kernels have not been considered for TM3.
3. SUMMARY COMPARISON WITH GROUND-BASED FTS

Recently the SCIAMACHY WFM-DOAS year 2003 data set has been compared with a network of ground based FTS stations [9]. Figure 4 gives an overview about the stations and the mean relative difference of SCIAMACHY CO and methane with respect to FTS. The main results of this comparison are summarized in Tab. 1.

<table>
<thead>
<tr>
<th>SCIAMACHY Data Product</th>
<th>N</th>
<th>Bias [%]</th>
<th>Scatter [%]</th>
<th>R [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO column</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WFM-DOAS v0.5</td>
<td>22362</td>
<td>-0.01</td>
<td>25.1</td>
<td>0.86</td>
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<tr>
<td>CO column averaged mixing ratio XCH₄</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WFM-DOAS v0.5 (SZA bias corrected)</td>
<td>42072</td>
<td>-3.28</td>
<td>1.93</td>
<td>0.80</td>
</tr>
<tr>
<td>WFM-DOAS v0.5 (not corrected)</td>
<td>42072</td>
<td>-4.09</td>
<td>3.36</td>
<td>0.72</td>
</tr>
<tr>
<td>Methane column averaged mixing ratio XCH₄</td>
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<tr>
<td>WFM-DOAS v0.5 (SZA bias corrected)</td>
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<td>42072</td>
<td>-4.09</td>
<td>3.36</td>
<td>0.72</td>
</tr>
<tr>
<td>Methane column averaged mixing ratio XCO₂</td>
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<td></td>
<td></td>
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<tr>
<td>WFM-DOAS v0.4 (limited comparison with three non-ideal stations)</td>
<td>7704</td>
<td>-6.95</td>
<td>3.78</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Tab. 1: Summary of the comparison of the SCIAMACHY WFM-DOAS v0.5/v0.4 CO, methane and CO₂ data set with ground based FTS measurements. N = number of SCIAMACHY measurements compared with the FTS measurements, Bias is the relative difference SCIA-FTS in percent, Scatter is the standard deviation of the difference in percent, and R is the correlation coefficient (more details are given in [9]).

Fig. 4: Comparison of SCIAMACHY CO columns (blue: WFM-DOAS version 0.5 = WFMDO) and methane column averaged mixing ratios (blue: WFMDO) with ground based FTS measurements (top right: list of stations). IMAP and IMLM are two independent retrieval algorithms developed by University of Heidelberg and SRON, respectively (see [9] for details).
5. CONCLUSIONS AND OUTLOOK

We have presented a short overview about the latest status of the retrieval of CO, methane and carbon dioxide columns from SCIAMACHY near-infrared nadir spectra (Level 1 version 4) using the WFM-DOAS algorithm. Our next steps are: Reprocessing of the year 2003 data set using Level 1 version 5 spectra (improved calibration) and processing and analysis of more data (2004, 2005, ...). Information about the latest status is given on our SCIAMACHY/WFM-DOAS web page:

http://www.iup.physik.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/index.html.

ACKNOWLEDGEMENTS

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REFERENCES