SCIAMACHY WFM-DOAS methane, carbon monoxide, and carbon dioxide columns: Algorithm description and product specification

Valid for:

Product	**Version**
Methane dry-air column averaged mixing ratio	0.5
CO vertical column	0.5
CO_2 dry-air column averaged mixing ratio	0.4

Table of contents

1 Purpose of document

To provide the algorithm description and product specification for the following scientific data products retrieved from near-infrared nadir spectra of the SCIAMACHY instrument onboard ENVISAT:

Product	Details	Algorithm	Current version
XCH4	XCH4 is the dry air column averaged mixing ratio of methane in ppbv	WFM-DOAS	0.5
CO columns	Vertical columns of carbon monoxide in molecules/cm2	WFM-DOAS	0.5
XCO2	XCO2 is the dry air column averaged mixing ratio of carbon dioxide in ppmv	WFM-DOAS	0.4

Basically all available information about or data products can be obtained from a dedicated WFM-DOAS web page:

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

Via this web page the following can be obtained: PDF files of papers, poster, technical reports, etc., averaging kernels and a-priori profiles (as ASCII files), sample data product files, global maps, data access information, point of contact information, etc.

The three data products are treated independently from each other. If a reader is interested in only one particular data product he/she only has to read the sections related to this product. This means, however, that this document contains redundant parts as certain information are identical for two or all three data products.

2 Algorithm description

2.1 Methane retrieval algorithm

Algorithm: WFM-DOAS v0.5

Most relevant reference: Buchwitz et al., 2006.

Validation: Dils et al., 2006

The algorithm is in detail described in Buchwitz et al., 2006. Here we limit ourselves to a short overview. For details including a full list of references please see Buchwitz et al., 2006.

2.1.1 Forward model

The forward model is the radiative transfer model SCIATRAN version 1.2 (Buchwitz et al., 2000a). SCIATRAN takes multiple scattering fully into account. SCIATRAN solves the radiative transfer equation for pseudo-spherical geometry and is valid for nadir observations (for the full range of SCIAMACHY scan angles) up to a solar zenith angle of about 92 degrees. To enable a fast retrieval, a look up table scheme for the radiances and their derivatives has been implemented.

2.1.2 Inversion procedure

WFM-DOAS is a modified DOAS algorithm. A linearized radiative transfer model plus a low order polynomial is linear least squares fitted to the logarithm of the measured sun-normalized radiance. The trace gas vertical profiles are scaled for the fit (i.e., the profile shape is not varied).

Spectral fitting window: 1629-1671 nm (channel 6)

Fit parameters:

- Scaling factor for methane column
- Scaling factor for CO_2 column
- Scaling factor for H_2O column
- Shift parameter for temperature profile
- Parameters for low order polynomial

In order to convert the methane column into a mixing ratio and to minimize systematic biases, the methane column is divided by the dry-air column obtained from the simultaneously measured CO_2 column. A constant value of the CO_2 VMR of 370 ppmv is assumed. The CO_2 column is the column of the WFM-DOAS version

0.4 data product also described in this document (this CO_2 column is also part of our methane data product).

2.1.3 Averaging kernels

Methane veraging kernels are shown in Buchwitz et al., 2005a.

They are available from (ASCII file):
http://www.iup.physik.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/wfmd_averaging_kernels.html

Note that these averaging kernels are for the version 0.4 product retrieved from a different spectral regions. The version 0.5 averaging kernels are expected to be similar but not exactly identical (update in preparation).

The corresponding a-priori profile is also available from this page (ASCII file).

2.1.4 Auxiliary data

Atmospheric profiles: US Standard atmosphere with methane and CO_2 scaled to 1750 ppbv and 370 ppbv, respectively. A single profile of temperature, pressure and trace gas mixing ratios is used for all retrievals. This a-priori profile is available from (ASCII file):
http://www.iup.physik.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/wfmd_averaging_kernels.html

Aerosol scenario: LOWTRAN/MODTRAN aerosol model for tropospheric maritime and normal stratospheric/mesospheric conditions. Details are given in Buchwitz and Burrows, 2004.

Spectroscopic parameters: HITRAN 2000 including 2003 updates (the reference is given in Buchwitz et al., 2006).

2.1.5 Error analysis and algorithm validation

The results of an error analysis of the retrieval with simulated spectra are given in Buchwitz et al., 2005a.

The data product has been extensively compared with global model simulations (see Buchwitz et al., 2006). Agreement is typically within a few percent.

2.1.6 Known issues

- Solar zenith angle dependent bias (see Buchwitz et al., 2006) due to a calibration problem of the Level 1 version 4 spectra

2.1.7 Future work

Algorithm improvements

- Reprocessing using version 5 spectra (this solves the solar zenith angle dependent bias problem)
- Use of improved spectroscopy, e.g., Hitran 2004
- Several minor improvements (e.g., better consideration of changing surface elevation/pressure, …)

Processing and analysis of more data (2004, 2005, …)

2.2 Carbon monoxide retrieval algorithm

Algorithm: WFM-DOAS v0.5

Most relevant reference: Buchwitz et al., 2006.

Validation: Dils et al., 2006

The algorithm is in detail described in Buchwitz et al., 2006. Here we limit ourselves to a short overview. For details including a full list of references please see Buchwitz et al., 2006.

2.2.1 Forward model

The forward model is the radiative transfer model SCIATRAN version 1.2 (Buchwitz et al., 2000a). SCIATRAN takes multiple scattering fully into account. SCIATRAN solves the radiative transfer equation for pseudo-spherical geometry and is valid for nadir observations (for the full range of SCIAMACHY scan angles) up to a solar zenith angle of about 92 degrees. To enable a fast retrieval, a look up table scheme for the radiances and their derivatives has been implemented.

2.2.2 Inversion procedure

WFM-DOAS is a modified DOAS algorithm. A linearized radiative transfer model plus a low order polynomial is linear least squares fitted to the logarithm of the measured sun-normalized radiance. The trace gas vertical profiles are scaled for the fit (i.e., the profile shape is not varied).

Spectral fitting window: 2324-2335 nm (channel 8)

Fit parameters:

- Scaling factor for CO column
- Scaling factor for methane column
- Scaling factor for H_2O column
- Shift parameter for temperature profile
- Parameters for low order polynomial

In order to minimize systematic biases, the CO column is scaled with a dimensionless factor. This factor is the a-priori methane column (computed assuming 3.6E19 molecules/cm^2 for a pixels with a surface elevation at sea level) divided by the simultaneously measured methane column from the same fitting window.

2.2.3 Averaging kernels

Averaging kernels are shown in in Buchwitz et al., 2004.

They are available from (ASCII file):
http://www.iup.physik.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/wfmd_averaging_kernels.html

Note that these averaging kernels are for the version 0.4 product retrieved from a different spectral regions. The version 0.5 averaging kernels are expected to be similar but not exactly identical (update in preparation).

The corresponding a-priori profile is also available from this page (ASCII file).

2.2.4 Auxiliary data

Atmospheric profiles: US Standard atmosphere with methane and CO_2 scaled to 1750 ppbv and 370 ppbv, respectively. A single profile of temperature, pressure and trace gas mixing ratios is used for all retrievals. This a-priori profile is available from (ASCII file):
http://www.iup.physik.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/wfmd_averaging_kernels.html

Aerosol scenario: LOWTRAN/MODTRAN aerosol model for tropospheric maritime and normal stratospheric/mesospheric conditions. Details are given in Buchwitz and Burrows, 2004.

Spectroscopic parameters: HITRAN 2000 including 2003 updates (the reference is given in Buchwitz et al., 2006).

2.2.5 Error analysis and algorithm validation

The results of an error analysis of the retrieval with simulated spectra are given in Buchwitz et al., 2004.

The data product has been extensively compared with the CO column data product of MOPITT (see Buchwitz et al., 2006). Agreement is typically within 10-20% percent (with SCIAMACHY typically higher compared to MOPITT). Regionally, esp. over South America, differences can be larger.

2.2.6 Known issues

- There still appears to be a residual error due to the ice layer of up to about 10-20% (see Buchwitz et al., 2006)

2.2.7 Future work

Algorithm improvements

- Reprocessing using version 5 spectra
- Use of improved spectroscopy, e.g., Hitran 2004
- Implementation of a more advanced correction scheme for ice-layer induced biases
- Implementation of an appropriate scheme to deal with the increasing number of dead/bad detector pixels

Processing and analysis of more data (2004, 2005, …)

2.3 Carbon dioxide retrieval algorithm

Algorithm: WFM-DOAS v0.4

Most relevant references: Buwitz et al., 2005a and 2005b (but also Buchwitz et al., 2006)

Validation: Dils et al., 2006

The algorithm is in detail described in Buchwitz et al., 2005a. Here we limit ourselves to a short overview. For details including a full list of references please see Buchwitz et al., 2005a.

2.3.1 Forward model

The forward model is the radiative transfer model SCIATRAN version 1.2 (Buchwitz et al., 2000a). SCIATRAN takes multiple scattering fully into account. SCIATRAN solves the radiative transfer equation for pseudo-spherical geometry and is valid for nadir observations (for the full range of SCIAMACHY scan angles) up to a solar zenith angle of about 92 degrees. To enable a fast retrieval, a look up table scheme for the radiances and their derivatives has been implemented.

2.3.2 Inversion procedure

WFM-DOAS is a modified DOAS algorithm. A linearized radiative transfer model plus a low order polynomial is linear least squares fitted to the logarithm of the measured sun-normalized radiance. The trace gas vertical profiles are scaled for the fit (i.e., the profile shape is not varied).

Spectral fitting window: 1558-1594 nm (channel 6)

Fit parameters:

- Scaling factor for CO_2 column
- Scaling factor for H_2O column
- Shift parameter for temperature profile
- Parameters for low order polynomial

In order to convert the CO2 column into a mixing ratio the CO2 column is divided by the dry-air column obtained from the simultaneously measured O_2 column obtained from the O_2 A band.

Details O_2 fit:

Spectral fitting window: 755-775 nm (channel 4)

Fit parameters:

- Scaling factor for O_2 column
- Albedo scaling factor
- Shift parameter for temperature profile
- Parameters for low order polynomial

2.3.3 Averaging kernels

The averaging kernels are shown in in Buchwitz et al., 2005a.

They are available from (ASCII file):
http://www.iup.physik.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/wfmd_averaging_kernels.html

The corresponding a-priori profile is also available from this page (ASCII file).

2.3.4 Auxiliary data

Atmospheric profiles: US Standard atmosphere with methane and CO_2 scaled to 1750 ppbv and 370 ppbv, respectively. A single profile of temperature, pressure and trace gas mixing ratios is used for all retrievals. This a-priori profile is available from (ASCII file):
http://www.iup.physik.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/wfmd_averaging_kernels.html

Aerosol scenario: LOWTRAN/MODTRAN aerosol model for tropospheric maritime and normal stratospheric/mesospheric conditions. Details are given in Buchwitz and Burrows, 2004.

Spectroscopic parameters: HITRAN 2000 including 2003 updates (the reference is given in Buchwitz et al., 2006).

2.3.5 Error analysis and algorithm validation

The results of an error analysis of the retrieval with simulated spectra are given in Buchwitz et al., 2005a.

The data product has been extensively compared with global model simulations (see Buchwitz et al., 2005a and 2005b). Agreement is typically within several percent.

2.3.6 Known issues

- The CO_2 columns are scaled with a constant factor of 1.27 (see Buchwitz et al., 2006) due to a calibration problem of the Level 1 version 4 spectra
- The O_2 columns are scaled with 0.85 (under investigation)

2.3.7 Future work

Algorithm improvements

- Reprocessing using version 5 spectra (this solves (at least to a large extent) the CO_2 scaling factor issue, see Buchwitz et al., 2006)
- Use of improved spectroscopy, e.g., Hitran 2004
- Implementation of a quality flag (as for methane and CO)
- Several minor improvements (e.g., reduction of albedo sensitivity, better consideration of changing surface elevation/pressure, …)

Processing and analysis of more data (2004, 2005, …)

3 Product specification

3.1 Methane product specification

3.1.1 Processed data

So far all available year 2003 data have been processed. An overview about the processed orbits is given in Buchwitz et al., 2005b.

3.1.2 Validation

The year 2003 data set has been compared with a network of ground based FTIR stations (Dils et al., 2006). Agreement with FTIR is within a few percent (details are given in Dils et al., 2006).

3.1.3 Known issues related to the product files

- None

3.1.4 Product file description

The SCIAMACHY WFM-DOAS product files are ASCII files consisting of a detailed header followed by a table with the data (one line per ground pixel). For each orbit one product file is generated. The horizontal resolution is typically: 30 x 60 km^2.

A sample product file is available from
http://www.iup.physik.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/index.html

An example of the file header is given on the following page. This file header contains a description of the content of all columns of the table of data that follows after the header.

Here we provide additional information for those columns where we think that additional information is needed:

Column#	**Comments**
3	Pixel type: 1 = nominal forward scan ground pixel; 2 = fast backscan pixel
19	Cloud mask: 0 = cloud free; 1 = cloud contaminated
20	Land mask: 0 = full pixel or part of pixel over water; 1 = land pixel
22	Absolute value of SCIAMACHY measured sun-normalized radiance
Main methane product:	
37	XCH4 product in ppbv
38	Percentage error of XCH4 product. Computed taking into account the quality of the spectral fit (RMS of fit residuum). The explicit formula is given in Buchwitz et al., 2005a.
39	XCH4 product quality flag 0 = quality OK 1 = quality not OK The quality flag is determined using a number of criteria (Buchwitz et al., 2006): Quality OK if: CH4 and CO2 column fit errors less than 10%; CH4 and CO2 columns within 20% of assumed (a-priori) column (3.6E19molecules/cm2 for CH4 and 8E21molecules/cm2 for CO2 for a ground pixel with an average surface elevation corresponding to sea level); SZA less than 88 deg; forward scan pixel (i.e., no fast back scan pixel because of four times larger ground pixel size); measurement over land.

Example of product file header:

```
# CH4 total columns from SCIAMACHY/ENVISAT orbit 04714_0547_…
# Generated by Ruediger.de_Beek@iup.physik.uni-bremen.de on …
# Level 1b file: SCI_NL__1POLRA20030124_092956_000060012013_0 …
# Sensing start:       24-JAN-2003 09:29:56.447883
# Sensing stop :       24-JAN-2003 11:09:58.002251
# Channel:   6
# Fitwindow: 1629.0 1671.0 nm
# Col 0: px#         : Ground pixel number (per orbit) [-] (1,2,...)
# Col 1: st#         : State number [-] (0,1,..)
# Col 2: read#       : Ground pixel number (per state) [-] (0,1,...)
# Col 3: t           : Pixel type [-] (1:forward 2:backscan)
# Col 4: dsr_time    : Starttime in frac.days since 1.1.2000 [day]
# Col 5: t_int       : Integration time [s]
# Col 6: lat_c       : Latitude  center   [deg]
# Col 7: lon_c       : Longitude center   [deg]
# Col 8: lat_1       : Latitude  corner 1 [deg]
# Col 9: lon_1       : Longitude corner 1 [deg]
# Col10: lat_2       : Latitude  corner 2 [deg]
# Col11: lon_2       : Longitude corner 2 [deg]
# Col12: lat_3       : Latitude  corner 3 [deg]
# Col13: lon_3       : Longitude corner 3 [deg]
# Col14: lat_4       : Latitude  corner 4 [deg]
# Col15: lon_4       : Longitude corner 4 [deg]
# Col16: sza         : Solar zenith angle [deg]
# Col17: los         : Line-of-sight zenith angle [deg]
# Col18: azi         : Relative azimuth angle [deg]
# Col19: cld         : Cloud mask (1: probably cloud contamin.)
# Col20: lnd         : Land mask (1: completely land covered)
# Col21: rms         : RMS of fit residuum [-]
# Col22: snrad       : Sun-normalized radiance (R/I*PI) [-]
# Col23: alt         : Average ground altitude [km]
# Col24: H2O         : H2O column [molec./cm2]
# Col25: H2O_err     : H2O column error [%]
# Col26: O2#         : Number of O2 (sub-)pixel [-]
# Col27: O2          : O2 column [molec./cm2]
# Col28: O2_err      : O2 column error [%]
# Col29: O2_qual     : O2 quality flag (1: bad)
# Col30: CO2#        : Number of CO2 (sub-)pixel [-]
# Col31: CO2         : CO2 column [molec./cm2]
# Col32: CO2_err     : CO2 column error [%]
# Col33: CO2_qual    : CO2 quality flag (1: bad)
# Col34: CH4         : CH4 column [molec./cm2]
# Col35: CH4_err     : CH4 column error [%]
# Col36: CH4_qual    : CH4 quality flag (1: bad)
# Col37: XCH4        : XCH4 [ppbv]
# Col38: XCH4_err    : XCH4 error [%]
# Col39: XCH4_qual   : XCH4 quality flag (1: bad)
#  px# st# read# t  …
…
```

Table with data

3.2 Carbon monoxide product specification

3.2.1 Processed data

So far all available year 2003 data have been processed. An overview about the processed orbits is given in Buchwitz et al., 2005b.

3.2.2 Validation

The year 2003 data set has been compared with a network of ground based FTIR stations (Dils et al., 2006). Agreement with FTIR is within about 10-30% (details are given in Dils et al., 2006).

3.2.3 Known issues related to the product files

- # Col26: CH4 : contains wrong values due to a formatting error

3.2.4 Product file description

The SCIAMACHY WFM-DOAS product files are ASCII files consisting of a detailed header followed by a table with the data (one line per ground pixel). For each orbit one product file is generated. The horizontal resolution is typically: 30 x 120 km^2.

A sample product file is available from
http://www.iup.physik.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/index.html

An example of the file header is given on the following page. This file header contains a description of the content of all columns of the table of data that follows after the header.

Here we provide additional information for those columns where we think that additional information is needed:

Column#	**Comments**
3	Pixel type: 1 = nominal forward scan ground pixel; 2 = fast backscan pixel
19	Cloud mask: 0 = cloud free; 1 = cloud contaminated
20	Land mask: 0 = full pixel or part of pixel over water; 1 = land pixel
22	Absolute value of SCIAMACHY measured sun-normalized radiance
Main CO product:	
30	CO product in molecules/cm2
31	Percentage error of CO product. Computed taking into account the quality of the spectral fit (RMS of fit residuum). The explicit formula is given in Buchwitz et al., 2004.
32	CO product quality flag 0 = quality OK 1 = quality not OK The quality flag is determined using a number of criteria (Buchwitz et al., 2006): Quality OK if: RMS of fit residuum < 2.5%; CO fiterror < 60%; CH4 fiterror < 3.6E18 molecules/cm2; CO column > 0; CH4 columns within 20% of assumed (a-priori) column (3.6E19molecules/cm2 for a ground pixel with an average surface elevation corresponding to sea level); SZA less than 88 deg; forward scan pixel (i.e., no fast back scan pixel because of four times larger ground pixel size).

Example of product file header:

```
# CO total columns from SCIAMACHY/ENVISAT orbit 04714_0547…
# Generated by Ruediger.de_Beek@iup.physik.uni-bremen.de on Do Apr …
# Level 1b file:       SCI_NL__1POLRA20030124_092956_0000…
# Sensing start:       24-JAN-2003 09:29:56.447883
# Sensing stop :       24-JAN-2003 11:09:58.002251
# Channel:   8
# Fitwindow: 2324.0 2335.0 nm
# Col 0: px#         : Ground pixel number (per orbit) [-] (1,2,...)
# Col 1: st#         : State number [-] (0,1,..)
# Col 2: read#       : Ground pixel number (per state) [-] (0,1,...)
# Col 3: t           : Pixel type [-] (1:forward 2:backscan)
# Col 4: dsr_time    : Starttime in frac.days since 1.1.2000 [day]
# Col 5: t_int       : Integration time [s]
# Col 6: lat_c       : Latitude  center   [deg]
# Col 7: lon_c       : Longitude center   [deg]
# Col 8: lat_1       : Latitude  corner 1 [deg]
# Col 9: lon_1       : Longitude corner 1 [deg]
# Col10: lat_2       : Latitude  corner 2 [deg]
# Col11: lon_2       : Longitude corner 2 [deg]
# Col12: lat_3       : Latitude  corner 3 [deg]
# Col13: lon_3       : Longitude corner 3 [deg]
# Col14: lat_4       : Latitude  corner 4 [deg]
# Col15: lon_4       : Longitude corner 4 [deg]
# Col16: sza         : Solar zenith angle [deg]
# Col17: los         : Line-of-sight zenith angle [deg]
# Col18: azi         : Relative azimuth angle [deg]
# Col19: cld         : Cloud mask (1: probably cloud contamin.)
# Col20: lnd         : Land mask (1: completely land covered)
# Col21: rms         : RMS of fit residuum [-]
# Col22: snrad       : Sun-normalized radiance (no data=-0.99999D+00)
# Col23: alt         : Average ground altitude [km]
# Col24: H2O         : H2O column [molec./cm2]
# Col25: H2O_err     : H2O column error [%]
# Col26: CH4         : CH4 column [molec./cm2]
# Col27: CH4_err     : CH4 column error [%]
# Col28: CO          : CO column [molec./cm2]
# Col29: CO_err      : CO column error [%]
# Col30: CO_corr     : CO product [molec./cm2]
# Col31: CO_corr_err: CO product error [%]
# Col32: CO_qual     : CO product quality flag (1: bad)
#  px# st# read# t      dsr_time    t_int   lat_c     lon_c   …
…
```

Table with data

3.3 Carbon dioxide product specification

3.3.1 Processed data

So far all available year 2003 data have been processed. An overview about the processed orbits is given in Buchwitz et al., 2005b.

3.3.2 Validation

The year 2003 data set has been compared with three ground based FTIR stations (Dils et al., 2006). Agreement with FTIR is within a few percent: a quite systematic low bias of 7% has been identified; the standard deviation relative to FTIR is 3-4%; the accuracy of the FTIR measurements is estimated to 3% (details are given in Dils et al., 2006).

3.3.3 Known issues related to the product files

- None

3.3.4 Product file description

The SCIAMACHY WFM-DOAS product files are ASCII files consisting of a detailed header followed by a table with the data (one line per ground pixel). For each orbit one product file is generated. The horizontal resolution is typically: 30 x 60 km^2.

A sample product file is available from
http://www.iup.physik.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/index.html

An example of the file header is given on the following page. This file header contains a description of the content of all columns of the table of data that follows after the header. Here we provide additional information for those columns where we think that additional information is needed:

Column#	**Comments**
3	Pixel type: 1 = nominal forward scan ground pixel; 2 = fast backscan pixel
19	Cloud mask: 0 = cloud free; 1 = cloud contaminated
21	Absolute value of SCIAMACHY measured sun-normalized radiance
Main XCO2 product:	
28	XCO2 product in ppmv
29	Percentage error of XCO2 product. Computed taking into account the quality of the spectral fit (RMS of fit residuum). The explicit formula is given in Buchwitz et al., 2005a.

Example of product file header:

```
# CO2 total columns from SCIAMACHY/ENVISAT orbit 04714_05…
# Generated by Ruediger.de_Beek@iup.physik.uni-bremen.de on Mon …
# Level 1b file:       SCI_NL__1POLRA20030124_092956_000060012013_00…
# Sensing start:       24-JAN-2003 09:29:56.447883
# Sensing stop :       24-JAN-2003 11:09:58.002251
# Channel:   6
# Fitwindow: 1558.0 - 1594.0 nm
# Col 0: px#         : Ground pixel number (per orbit) [-] (1,2,...)
# Col 1: st#         : State number [-] (0,1,..)
# Col 2: read#       : Ground pixel number (per state) [-] (0,1,...)
# Col 3: t           : Pixel type [-] (1:forward 2:backscan)
# Col 4: dsr_time    : Starttime in frac.days since 1.1.2000 [day]
# Col 5: t_int       : Integration time [s]
# Col 6: lat_c       : Latitude  center   [deg]
# Col 7: lon_c       : Longitude center   [deg]
# Col 8: lat_1       : Latitude  corner 1 [deg]
# Col 9: lon_1       : Longitude corner 1 [deg]
# Col10: lat_2       : Latitude  corner 2 [deg]
# Col11: lon_2       : Longitude corner 2 [deg]
# Col12: lat_3       : Latitude  corner 3 [deg]
# Col13: lon_3       : Longitude corner 3 [deg]
# Col14: lat_4       : Latitude  corner 4 [deg]
# Col15: lon_4       : Longitude corner 4 [deg]
# Col16: sza         : Solar zenith angle [deg]
# Col17: los         : Line-of-sight zenith angle [deg]
# Col18: azi         : Relative azimuth angle [deg]
# Col19: cld         : Cloud mask (1: probably cloud contamin.)
# Col20: rms         : RMS of fit residuum [-]
# Col21: snrad       : Sun-normalized radiance (R/I*PI) [-]
# Col22: alt         : Average ground altitude [km]
# Col23: O2#         : Number of O2 (sub-)pixel [-]
# Col24: O2          : O2 column [molec./cm2]
# Col25: O2_err      : O2 column error [%]
# Col26: CO2         : CO2 column [molec./cm2]
# Col27: CO2_err     : CO2 column error [%]
# Col28: XCO2        : XCO2 [ppmv]
# Col29: XCO2_err    : XCO2 error [%]
# Col30: H2O         : H2O column [molec./cm2]
# Col31: H2O_err     : H2O column error [%]
#  px# st# read# t      dsr_time    t_int   lat_c     lon_c   …
```

…

Table with data

4 References

An full reference list including latest updates and links to PDF files of the papers is given here:

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

Buchwitz, M., R. de Beek, S. Noël, J. P. Burrows, H. Bovensmann, O. Schneising, I. Khlystova, M. Bruns, H. Bremer, P. Bergamaschi , S. Körner, and M. Heimann, Atmospheric carbon gases retrieved from SCIAMACHY by WFM-DOAS: version 0.5 CO and CH_4 and impact of calibration improvements on CO_2 retrieval, Atmos. Chem. Phys. (in press), 2006.

PDF file available from Michael.Buchwitz@iup.physik.uni-bremen.de on request

Buchwitz, M., R. de Beek, S. Noël, J. P. Burrows, H. Bovensmann, H. Bremer, P. Bergamaschi, S. Körner, M. Heimann, Carbon monoxide, methane and carbon dioxide columns retrieved from SCIAMACHY by WFM-DOAS: year 2003 initial data set, Atmos. Chem. Phys., 5, 3313-3329, 2005b.

Buchwitz, M., R. de Beek, J. P. Burrows, H. Bovensmann, T. Warneke, J. Notholt, J. F. Meirink, A. P. H. Goede, P. Bergamaschi, S. Körner, M. Heimann, and A. Schulz, Atmospheric methane and carbon dioxide from SCIAMACHY satellite data: Initial comparison with chemistry and transport models, Atmos. Chem. Phys., 5, 941-962, 2005a.

Buchwitz, M., R. de Beek, K. Bramstedt, S. Noël, H. Bovensmann, and J. P. Burrows, Global carbon monoxide as retrieved from SCIAMACHY by WFM-DOS, Atmos. Chem. Phys., 4, 1954-1960, 2004.

Buchwitz, M., and John P. Burrows, Retrieval of CH4, CO, and CO2 total column amounts from SCIAMACHY near-infrared nadir spectra: Retrieval algorithm and first results, Proceedings of SPIE 5235, Remote Sensing of Clouds and the Atmosphere VIII, K. P. Schäfer and A. Comeron and M. R. Carleer and R. H. Picard (Editors), 375-388, 2004.

Buchwitz, M., V.V. Rozanov, and J.P. Burrows, A near-infrared optimized DOAS method for the fast global retrieval of atmospheric CH_4, CO, CO_2, H_2O, and N_2O total column amounts from SCIAMACHY Envisat-1 nadir radiances, J. Geophys. Res. 105, 15,231-15,245, 2000b.

Buchwitz, M., V.V. Rozanov, and J.P. Burrows, A correlated-*k* distribution scheme for overlapping gases suitable for retrieval of atmospheric constituents from moderate resolution radiance measurements in the visible/near-infrared spectral region, J. Geophys. Res. 105, 15,247-15,261, 2000a.

Dils, B., M. De Mazière, J. F. Müller, T. Blumenstock, M. Buchwitz, R. de Beek, P. Demoulin, P. Duchatelet, H. Fast, C. Frankenberg, A. Gloudemans, D. Griffith, N. Jones, T. Kerzenmacher, E. Mahieu, J. Mellqvist, S. Mikuteit, R. L. Mittermeier, J. Notholt, H. Schrijver, D. Smale, A. Strandberg, W. Stremme, K. Strong, R. Sussmann, J. Taylor, M. van den Broek, T. Warneke, A. Wiacek, S. Wood,' Comparisons between SCIAMACHY and ground-based FTIR data for total columns of CO, CH_4, CO_2 and N_2O, Atmos. Chem. Phys., 6, 1953-1967, 2006.

Sussmann, R., M. Buchwitz, Initial validation of ENVISAT/SCIAMACHY columnar CO by FTIR profile retrievals at the Ground-Truthing Station Zugspitze, Atmos. Chem. Phys., 5, 1497-1503, 2005.

Sussmann, R., W. Stremme, M. Buchwitz, R. de Beek, Validation of ENVISAT/SCIAMACHY columnar methane by solar FTIR spectrometry at the Ground-Truthing Station Zugspitze, Atmos. Chem. Phys., 5, 2419-2429, 2005.

Warneke, T., de Beek, R., Buchwitz, M., Notholt, J., Schulz, A., Velazco, V., and Schrems, O., Shipborne solar absorption measurements of CO_2, CH_4, N_2O, and CO and comparison the SCIAMACHY WFM-DOAS retrievals, Atmos. Chem. Phys., 5, 2029-2034, 2005.