ESA Climate Change Initiative (CCI)

Product User Guide (PUG)

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SCIAMACHY WFM-DOAS (WFMD)

XCO_2 and XCH_4

for the Essential Climate Variable (ECV)

Greenhouse Gases (GHG)

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Product User Guide (PUG)

SCIAMACHY WFM-DOAS (WFMD) XCO_2 and XCH_4

Prepared by:

Oliver Schneising

Valid for:

SCIAMACHY WFM-DOAS

Product	**Version**
Carbon dioxide column-averaged dry air mole fraction (XCO_2)	WFMDv3.9
Methane column-averaged dry air mole fraction (XCH_4)	WFMDv3.9

Contents

1 Purpose of document

This document describes the WFM-DOAS XCO_2 and XCH_4 data products illustrating how to use them.

2 Introduction

2.1 The SCIAMACHY instrument

The grating spectrometer SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY), which is a multinational (Germany, The Netherlands, Belgium) contribution to the European environmental satellite ENVISAT, measures reflected, backscattered and transmitted solar radiation at moderately high spectral resolution (0.2–1.4 nm) in the spectral region from 214 nm to 2386 nm (Burrows et al., 1990, 1995; Burrows and Chance, 1991; Bovensmann et al., 1999).

ENVISAT was launched into a sun-synchronous orbit in descending node having an equator crossing time of 10:00 a.m. local time. SCIAMACHY's observations of greenhouse gas overtone absorptions in the near-infrared/shortwave infrared (NIR/SWIR) solar backscattered spectrum yield the vertical columns of CO_2 and CH_4 with high sensitivity down to the Earth's surface (Buchwitz et al., 2005a). The instrument scans $\pm 32°$ across track around the nadir direction resulting in a swath width of 960 km consisting of single measurements with a horizontal resolution of typically 60 km across track by 30 km along track each for the spectral regions used in the XCO_2 and XCH_4 retrieval.

2.2 The WFM-DOAS retrieval algorithm

The Weighting Function Modified DOAS (WFM-DOAS) algorithm (Buchwitz et al., 2005a,b; Schneising et al., 2008, 2009, 2011, 2012; Heymann et al., 2012a,b; Schneising et al., 2013, 2014a,b) is a least-squares method based on scaling pre-selected atmospheric vertical profiles. The column-averaged dry air mole fractions of carbon dioxide and methane (denoted XCO_2 and XCH_4) are obtained from the vertical column amounts of the greenhouse gases by normalising with the air column, which can be determined by a simultaneously measured gas with less variability. The corresponding vertical column amounts are retrieved using small spectral fitting windows in the near-infrared/shortwave-infrared (NIR/SWIR) spectral region (1558-1594 nm and 1630-1671 nm, respectively) as well as the oxygen A-band (755-775 nm).

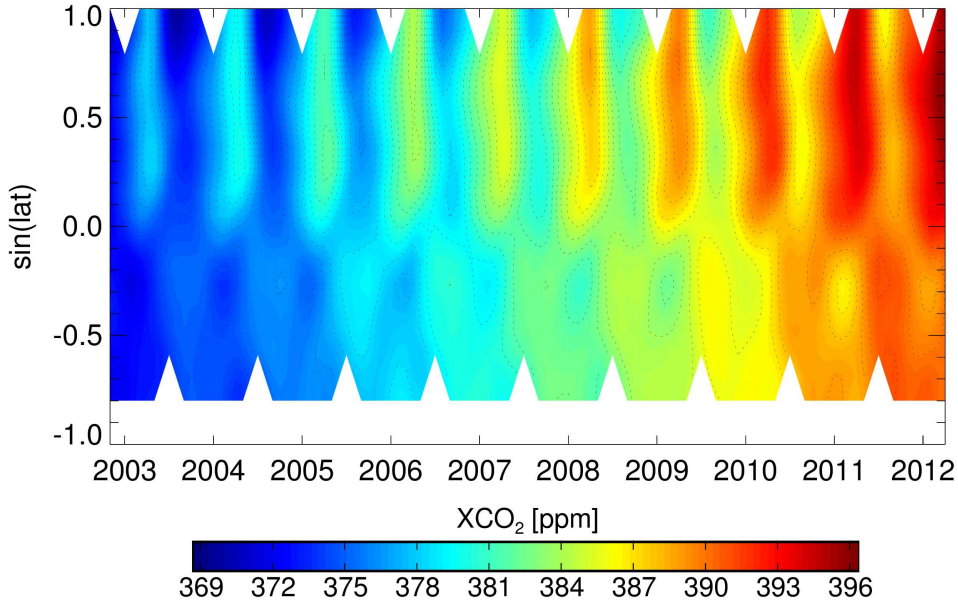

Figure 1: Overview of the WFMDv3.9 carbon dioxide data set; shown are column-averaged dry air mole fractions as a function of latitude and time.

2.3 XCO_2

The carbon dioxide mole fractions as a function of latitude and time are shown in Figure 1 demonstrating the pronounced seasonal cycle in the northern hemisphere due to the temporally varying imbalance between photosynthesis and respiration of vegetation and the global steady increase of atmospheric carbon dioxide primarily caused by the burning of fossil fuels.

From the validations with ground-based Fourier Transform Spectroscopy (FTS) measurements of the Total Carbon Column Observing Network (TCCON) (Wunch et al., 2011) and comparisons with the assimilation system CarbonTracker (Peters et al., 2007) at 10 TCCON sites, namely Sodankylä (Finland), Białystok (Poland), Karlsruhe (Germany), Orléans (France), Garmisch (Germany), Park Falls (USA), Lamont (USA), Darwin (Australia), Wollongong (Australia), and Lauder (New Zealand), realistic error estimates of the satellite data are provided and summarised in Table 1. The relevant parameters for quality assessment are the global offset which is defined as the mean of the local offsets at the individual sites, the random error which is the standard deviation of the differences to the reference using all data combined after subtraction of the respective regional biases, and the systematic error which is the standard deviation of the local offsets relative to TCCON or CarbonTracker at the individual sites. The temporal stability is

Table 1: Validation and comparison results for WFMDv3.9 XCO_2 based on single measurements between January 2003 and April 2012.

		SCIA-TCCON	SCIA-CT
Global Offset	[ppm]	0.9	−0.1
Random Error	[ppm]	3.0	3.0
Systematic Error	[ppm]	0.57	0.53
Stability	[ppm/yr]	0.01	0.04

determined by a linear fit of the differences relative to the reference (using all data combined after subtraction of the respective regional biases) with time. Please note, that the random error defined above includes systematic components and is therefore an upper bound of the actual single measurement precision characterising the repeatability of the measurements.

2.4 XCH_4

The methane mole fractions as a function of latitude and time are shown in Figure 2. The retrieved methane results show that after years of stability, atmospheric methane has started to rise again in recent years which is consistent with surface measurements (Rigby et al., 2008; Dlugokencky et al., 2009). Major methane source regions like the Sichuan Basin in China which is famous for rice cultivation and the interhemispheric gradient with larger methane concentrations in the Northern Hemisphere are clearly visible in the data (see Figure 3).

From the validations with ground-based Fourier Transform Spectroscopy (FTS) measurements of the Total Carbon Column Observing Network (TCCON) (Wunch et al., 2011) and comparisons with the TM5-4DVAR model (Bergamaschi et al., 2009, 2010) at the 10 TCCON sites listed above, realistic error estimates of the satellite data are provided and summarised in Table 2. The relevant parameters for quality assessment are the global offset which is defined as the mean of the local offsets at the individual sites, the random error which is the standard deviation of the differences to the reference using all data combined after subtraction of the respective regional biases, and the systematic error which is the standard deviation of the local offsets relative to TCCON or TM5-4DVAR at the individual sites. The temporal stability is determined by a linear fit of the differences relative to the reference (using all data combined after subtraction of the respective regional biases) with time.

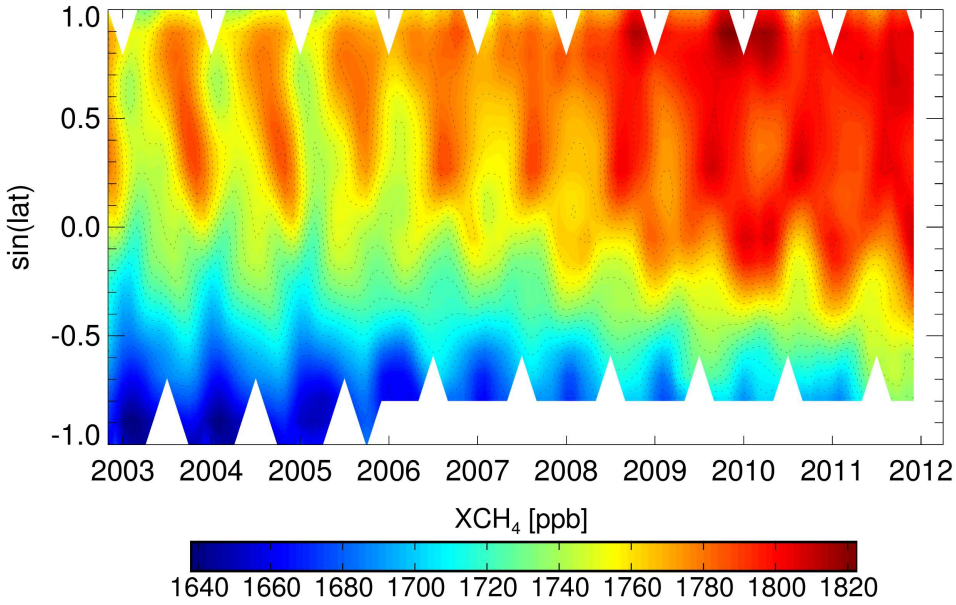

Figure 2: Overview of the long-term global WFMDv3.9 methane data set; shown are column-averaged dry air mole fractions as a function of latitude and time.

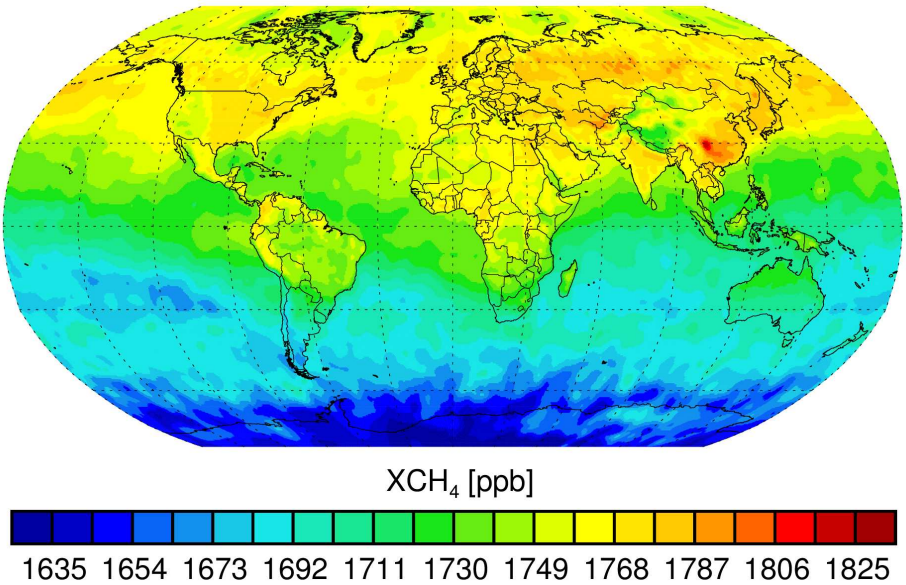

Figure 3: Three years mean (2003–2005) of retrieved SCIAMACHY WFMDv3.9 methane.

Table 2: Validation and comparison results for WFMDv3.9 XCH_4 based on single measurements between beginning of 2003 and end of 2011. Note that the TCCON validation focuses on the period after the pixel mask change as a consequence of lack of TCCON measurements before November 2005. For the TM5 comparison, the values in brackets correspond to the two periods before and after the pixel mask change at the beginning of November 2005.

		SCIA-TCCON	SCIA-TM5
Global Offset	[ppb]	−1	8
Random Error	[ppb]	80	66 (34; 81)
Systematic Error	[ppb]	6.9	3.7 (2.6; 6.5)
Stability	[ppb/yr]	0.17	0.00

Please note, that the random error defined above includes systematic components and is therefore an upper bound of the actual single measurement precision characterising the repeatability of the measurements. The single ground pixel retrieval precision derived from averaging daily standard deviations of the retrieved XCH_4 for several locations distributed around the globe provides an estimate of the single measurement precision of about 30 ppb before and 70 ppb after the pixel mask change at the beginning of November 2005, which is necessary because of displacement damage at individual detector pixels induced by high energy solar protons (Kleipool et al., 2007).

3 Product description

3.1 Product content and format

The CO2-SCIAMACHY-WFMD and CH4-SCIAMACHY-WFMD data products are stored per day in seperate NetCDF-files (NetCDF-4 classic model). The product files contain the key products, i.e. the retrieved column-averaged dry air mole fractions XCO_2 or XCH_4 and several other useful parameters (see Section 3.5 for details). Information relevant for the use of the data is also included in the data file, e.g. the averaging kernels.

3.2 Data usage

The column-averaged dry air mole fractions of carbon dioxide are stored in the variable `xco2` in the NetCDF product files `ESACCI-GHG-L2-CO2-SCIAMACHY-WFMD-YYYYMMDD-fv1.nc` (see Section 3.5).

Concerning XCH_4 data, please use the variable `xch4` in the corresponding product files `ESACCI-GHG-L2-CH4-SCIAMACHY-WFMD-YYYYMMDD-fv1.nc`.

If the data are to be compared with other data for which vertical profile information is available (e.g. comparison to models), the column averaging kernels should be applied to the model profiles using the formula

$$\mathrm{X}_{\mathrm{mod}} = \sum_l \left(\mathrm{X}^l_{\mathrm{apr}} + AK^l (\mathrm{X}^l_{\mathrm{mod}} - \mathrm{X}^l_{\mathrm{apr}}) \right) w^l \qquad (1)$$

where l is the index of the vertical layer, AK^l the averaging kernel (variables `xco2_averaging_kernel` and `xch4_averaging_kernel` in NetCDF product files), $\mathrm{X}^l_{\mathrm{apr}}$ the a-priori mole fraction (variables `co2_profile_apriori` and `ch4_profile_apriori` in product files) and $\mathrm{X}^l_{\mathrm{mod}}$ the simulated mole fraction of layer l. w^l is the layer dependent pressure weight (variable `pressure_weight` in product files).

3.3 Tools for Reading the Data

The data are stored in NetCDF format (NetCDF-4 classic model) which can be read with standard tools in the common programming languages (IDL, Matlab, Python, Fortran90, C++, etc).

3.4 Known Limitations and Issues

The XCH_4 results since November 2005 are considered to be of reduced quality (in comparison to the earlier results) because the extended-wavelength part (1590—1770 nm) of SCIAMACHY's channel 6, covering the methane $2\nu_3$ absorption band used for the methane retrieval, is subject to irreversible displacement damage induced by high energy solar protons, which occurs from time to time at individual detector pixels (Kleipool et al., 2007). Therefore, several affected detector pixels had to be excluded for the time period since November 2005.

3.5 Data file content

XCO_2

The structure of the Level2 product files `ESACCI-GHG-L2-CO2-SCIAMACHY-WFMD-YYYYMMDD-fv1.nc` is summarised in the following:

```
netcdf ESACCI-GHG-L2-CO2-SCIAMACHY-WFMD-20070701-fv1 {
dimensions:
    sounding_dim = 1893 ;
    level_dim = 21 ;
    layer_dim = 20 ;
    corners_dim = 4 ;
variables:
    double time(sounding_dim) ;
       time:standard_name = "time" ;
       time:long_name = "time" ;
       time:units = "seconds since 1970-01-01 00:00:00" ;
       time:calendar = "standard" ;
    float latitude(sounding_dim) ;
       latitude:standard_name = "latitude" ;
       latitude:long_name = "latitude" ;
       latitude:units = "degree_north" ;
       latitude:valid_range = -90.f, 90.f ;
       latitude:comment = "Center latitude of the measurement" ;
    float longitude(sounding_dim) ;
       longitude:standard_name = "longitude" ;
       longitude:long_name = "longitude" ;
       longitude:units = "degree_east" ;
       longitude:valid_range = -180.f, 180.f ;
       longitude:comment = "Center longitude of the measurement" ;
    float solar_zenith_angle(sounding_dim) ;
       solar_zenith_angle:standard_name = "solar_zenith_angle" ;
       solar_zenith_angle:long_name = "solar zenith angle" ;
       solar_zenith_angle:units = "degree" ;
       solar_zenith_angle:comment = "Solar zenith angle is the angle between the line
                of sight to the sun and the local vertical." ;
    float sensor_zenith_angle(sounding_dim) ;
       sensor_zenith_angle:standard_name = "sensor_zenith_angle" ;
       sensor_zenith_angle:long_name = "sensor zenith angle" ;
       sensor_zenith_angle:units = "degree" ;
       sensor_zenith_angle:comment = "Sensor zenith angle is the angle between the line
                of sight to the sensor and the local vertical." ;
    float xco2(sounding_dim) ;
       xco2:long_name = "column-averaged dry air mole fraction of atmospheric carbon dioxide" ;
       xco2:units = "1e-6" ;
       xco2:comment = "Retrieved column-averaged dry air mole fraction of atmospheric
                carbon dioxide (XCO2) in ppm" ;
    float xco2_uncertainty(sounding_dim) ;
       xco2_uncertainty:long_name = "1-sigma uncertainty of the retrieved column-averaged
                dry air mole fraction of atmospheric carbon dioxide" ;
       xco2_uncertainty:units = "1e-6" ;
       xco2_uncertainty:comment = "1-sigma uncertainty of the retrieved column-averaged
                dry air mole fraction of atmospheric carbon dioxide (XCO2) in ppm" ;
    byte xco2_quality_flag(sounding_dim) ;
       xco2_quality_flag:long_name = "quality flag" ;
       xco2_quality_flag:flag_values = 0b, 1b ;
       xco2_quality_flag:flag_meanings = "good_quality potentially_bad_quality" ;
       xco2_quality_flag:comment = "0=good, 1=bad" ;
```

```
float pressure_levels(sounding_dim, level_dim) ;
   pressure_levels:long_name = "pressure levels" ;
   pressure_levels:units = "hPa" ;
   pressure_levels:comment = "Pressure levels define the boundaries of the averaging
            kernel and a priori profile layers.\n",
           "Levels are ordered from surface to top of atmosphere." ;
float co2_profile_apriori(sounding_dim, layer_dim) ;
   co2_profile_apriori:long_name = "a priori dry air mole fraction profile of atmospheric
            carbon dioxide" ;
   co2_profile_apriori:units = "1e-6" ;
   co2_profile_apriori:comment = "A priori dry-air mole fraction profile of atmospheric
            carbon dioxide in ppm.\n",
           "All values represent layer averages within the corresponding pressure levels.\n",
           "Profiles are ordered from surface to top of atmosphere." ;
float xco2_averaging_kernel(sounding_dim, layer_dim) ;
   xco2_averaging_kernel:long_name = "xco2 averaging kernel" ;
   xco2_averaging_kernel:units = "1" ;
   xco2_averaging_kernel:comment = "Represents the altitude sensitivity of the retrieval as
             a function of pressure.\n",
            "All values represent layer averages within the corresponding pressure levels.\n",
            "Profiles are ordered from surface to top of atmosphere." ;
float pressure_weight(sounding_dim, layer_dim) ;
   pressure_weight:long_name = "pressure weight" ;
   pressure_weight:units = "1" ;
   pressure_weight:comment = "Layer dependent weights needed to apply the averaging kernels." ;
int64 orbit_number(sounding_dim) ;
   orbit_number:long_name = "orbit number" ;
   orbit_number:units = "1" ;
   orbit_number:comment = "Orbit number" ;
short scene_number(sounding_dim) ;
   scene_number:long_name = "ground scene number" ;
   scene_number:units = "1" ;
   scene_number:comment = "Ground scene number (per orbit)" ;
short state_number(sounding_dim) ;
   state_number:long_name = "state number" ;
   state_number:units = "1" ;
   state_number:comment = "State number (per orbit)" ;
float latitude_corners(sounding_dim, corners_dim) ;
   latitude_corners:long_name = "corner latitudes" ;
   latitude_corners:units = "degree_north" ;
   latitude_corners:valid_range = -90.f, 90.f ;
   latitude_corners:comment = "Corner latitudes of the measurement" ;
float longitude_corners(sounding_dim, corners_dim) ;
   longitude_corners:long_name = "corner longitudes" ;
   longitude_corners:units = "degree_east" ;
   longitude_corners:valid_range = -180.f, 180.f ;
   longitude_corners:comment = "Corner longitudes of the measurement" ;
float altitude(sounding_dim) ;
   altitude:standard_name = "altitude" ;
   altitude:long_name = "altitude" ;
   altitude:units = "m" ;
   altitude:comment = "Average surface altitude" ;
float h2o_column(sounding_dim) ;
   h2o_column:long_name = "vertical column of water vapour" ;
   h2o_column:units = "g cm-2" ;
   h2o_column:comment = "Retrieved vertical column amount of water vapour" ;
float surface_albedo_750nm(sounding_dim) ;
   surface_albedo_750nm:long_name = "surface albedo at 750nm" ;
   surface_albedo_750nm:units = "1" ;
   surface_albedo_750nm:comment = "Retrieved surface albedo at 750nm" ;
```

```
    float surface_albedo_1560nm(sounding_dim) ;
       surface_albedo_1560nm:long_name = "surface albedo at 1560nm" ;
       surface_albedo_1560nm:units = "1" ;
       surface_albedo_1560nm:comment = "Retrieved surface albedo at 1560nm" ;

// global attributes:
    :title = "ESA CCI SCIAMACHY WFMD XCO2" ;
    :institution = "University of Bremen" ;
    :source = "SCIAMACHY L1B version 7.xx (consolidation W)" ;
    :history = "2015 - product generated with WFMD" ;
    :references = "http://www.esa-ghg-cci.org/\n",
            "http://dx.doi.org/10.5194/acp-11-2863-2011\n",
            "http://dx.doi.org/10.5194/acp-13-2445-2013\n",
            "http://dx.doi.org/10.5194/acp-14-133-2014" ;
    :tracking_id = "62b0e958-41bb-4252-8b99-c59ae2cc78a8" ;
    :Conventions = "CF-1.6" ;
    :product_version = "v3.9" ;
    :summary = "Weighting Function Modified DOAS (WFMD) is designed to retrieve column-averaged
             dry air mole fractactions of atmospheric carbon dioxide and methane from the
             near-infrared/shortwave-infrared (NIR/SWIR) nadir spectra of the SCIAMACHY instrument
             onboard ENVISAT." ;
    :keywords = "satellite, ENVISAT, SCIAMACHY, atmosphere, carbon dioxide" ;
    :id = "ESACCI-GHG-L2-CO2-SCIAMACHY-WFMD-20070701-fv1.nc" ;
    :naming_authority = "iup.uni-bremen.de" ;
    :keywords_vocabulary = "NASA Global Change Master Directory (GCMD)" ;
    :cdm_data_type = "point" ;
    :comment = "These data were produced at the University of Bremen in the framework of the
             ESA GHG-CCI project" ;
    :date_created = "20150427T130403Z" ;
    :creator_name = "University of Bremen, IUP, Oliver Schneising" ;
    :creator_url = "http://www.iup.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/products/" ;
    :creator_email = "schneising@iup.physik.uni-bremen.de" ;
    :project = "Climate Change Initiative - European Space Agency" ;
    :geospatial_lat_min = -90.f ;
    :geospatial_lat_max = 90.f ;
    :geospatial_lat_units = "degree_north" ;
    :geospatial_lon_min = -180.f ;
    :geospatial_lon_max = 180.f ;
    :geospatial_lon_units = "degree_east" ;
    :geospatial_vertical_min = 0.f ;
    :geospatial_vertical_max = 100000.f ;
    :time_coverage_start = "20070701T000000Z" ;
    :time_coverage_end = "20070701T235959Z" ;
    :time_coverage_duration = "P1D" ;
    :time_coverage_resolution = "P1D" ;
    :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Conventions Version 1.6" ;
    :license = "ESA CCI Data Policy: free and open access" ;
    :platform = "ENVISAT" ;
    :sensor = "SCIAMACHY" ;
    :spatial_resolution = "30km x 60km at nadir (typically)" ;
}
```

XCH_4

The structure of the Level2 product files `ESACCI-GHG-L2-CH4-SCIAMACHY-WFMD-YYYYMMDD-fv1.nc` is summarised in the following:

```
netcdf ESACCI-GHG-L2-CH4-SCIAMACHY-WFMD-20070701-fv1 {
dimensions:
    sounding_dim = 4355 ;
    level_dim = 21 ;
    layer_dim = 20 ;
    corners_dim = 4 ;
variables:
    double time(sounding_dim) ;
       time:standard_name = "time" ;
       time:long_name = "time" ;
       time:units = "seconds since 1970-01-01 00:00:00" ;
       time:calendar = "standard" ;
    float latitude(sounding_dim) ;
       latitude:standard_name = "latitude" ;
       latitude:long_name = "latitude" ;
       latitude:units = "degree_north" ;
       latitude:valid_range = -90.f, 90.f ;
       latitude:comment = "Center latitude of the measurement" ;
    float longitude(sounding_dim) ;
       longitude:standard_name = "longitude" ;
       longitude:long_name = "longitude" ;
       longitude:units = "degree_east" ;
       longitude:valid_range = -180.f, 180.f ;
       longitude:comment = "Center longitude of the measurement" ;
    float solar_zenith_angle(sounding_dim) ;
       solar_zenith_angle:standard_name = "solar_zenith_angle" ;
       solar_zenith_angle:long_name = "solar zenith angle" ;
       solar_zenith_angle:units = "degree" ;
       solar_zenith_angle:comment = "Solar zenith angle is the the angle between the line
                of sight to the sun and the local vertical." ;
    float sensor_zenith_angle(sounding_dim) ;
       sensor_zenith_angle:standard_name = "sensor_zenith_angle" ;
       sensor_zenith_angle:long_name = "sensor zenith angle" ;
       sensor_zenith_angle:units = "degree" ;
       sensor_zenith_angle:comment = "Sensor zenith angle is the angle between the line
                of sight to the sensor and the local vertical." ;
    float xch4(sounding_dim) ;
       xch4:long_name = "column-averaged dry air mole fraction of atmospheric methane" ;
       xch4:units = "1e-9" ;
       xch4:comment = "Retrieved column-averaged dry air mole fraction of atmospheric
                methane (XCH4) in ppb" ;
    float xch4_uncertainty(sounding_dim) ;
       xch4_uncertainty:long_name = "1-sigma uncertainty of the retrieved column-averaged
                dry air mole fraction of atmospheric methane" ;
       xch4_uncertainty:units = "1e-9" ;
       xch4_uncertainty:comment = "1-sigma uncertainty of the retrieved column-averaged
                dry air mole fraction of atmospheric methane (XCH4) in ppb" ;
    byte xch4_quality_flag(sounding_dim) ;
       xch4_quality_flag:long_name = "quality flag" ;
       xch4_quality_flag:flag_values = 0b, 1b ;
       xch4_quality_flag:flag_meanings = "good_quality potentially_bad_quality" ;
       xch4_quality_flag:comment = "0=good, 1=bad" ;
    float pressure_levels(sounding_dim, level_dim) ;
       pressure_levels:long_name = "pressure levels" ;
```

```
   pressure_levels:units = "hPa" ;
   pressure_levels:comment = "Pressure levels define the boundaries of the averaging
            kernel and a priori profile layers.\n",
           "Levels are ordered from surface to top of atmosphere." ;
float ch4_profile_apriori(sounding_dim, layer_dim) ;
   ch4_profile_apriori:long_name = "a priori dry air mole fraction profile of
            atmospheric methane" ;
   ch4_profile_apriori:units = "1e-9" ;
   ch4_profile_apriori:comment = "A priori dry-air mole fraction profile of
            atmospheric methane in ppb.\n",
           "All values represent layer averages within the corresponding pressure levels.\n",
           "Profiles are ordered from surface to top of atmosphere." ;
float xch4_averaging_kernel(sounding_dim, layer_dim) ;
   xch4_averaging_kernel:long_name = "xch4 averaging kernel" ;
   xch4_averaging_kernel:units = "1" ;
   xch4_averaging_kernel:comment = "Represents the altitude sensitivity of the retrieval as
            a function of pressure.\n",
           "All values represent layer averages within the corresponding pressure levels.\n",
           "Profiles are ordered from surface to top of atmosphere." ;
float pressure_weight(sounding_dim, layer_dim) ;
   pressure_weight:long_name = "pressure weight" ;
   pressure_weight:units = "1" ;
   pressure_weight:comment = "Layer dependent weights needed to apply the averaging kernels." ;
int64 orbit_number(sounding_dim) ;
   orbit_number:long_name = "orbit number" ;
   orbit_number:units = "1" ;
   orbit_number:comment = "Orbit number" ;
short scene_number(sounding_dim) ;
   scene_number:long_name = "ground scene number" ;
   scene_number:units = "1" ;
   scene_number:comment = "Ground scene number (per orbit)" ;
short state_number(sounding_dim) ;
   state_number:long_name = "state number" ;
   state_number:units = "1" ;
   state_number:comment = "State number (per orbit)" ;
float latitude_corners(sounding_dim, corners_dim) ;
   latitude_corners:long_name = "corner latitudes" ;
   latitude_corners:units = "degree_north" ;
   latitude_corners:valid_range = -90.f, 90.f ;
   latitude_corners:comment = "Corner latitudes of the measurement" ;
float longitude_corners(sounding_dim, corners_dim) ;
   longitude_corners:long_name = "corner longitudes" ;
   longitude_corners:units = "degree_east" ;
   longitude_corners:valid_range = -180.f, 180.f ;
   longitude_corners:comment = "Corner longitudes of the measurement" ;
float altitude(sounding_dim) ;
   altitude:standard_name = "altitude" ;
   altitude:long_name = "altitude" ;
   altitude:units = "m" ;
   altitude:comment = "Average surface altitude" ;
float h2o_column(sounding_dim) ;
   h2o_column:long_name = "vertical column of water vapour" ;
   h2o_column:units = "g cm-2" ;
   h2o_column:comment = "Retrieved vertical column amount of water vapour" ;
float surface_albedo_750nm(sounding_dim) ;
   surface_albedo_750nm:long_name = "surface albedo at 750nm" ;
   surface_albedo_750nm:units = "1" ;
   surface_albedo_750nm:comment = "Retrieved surface albedo at 750nm" ;
float surface_albedo_1560nm(sounding_dim) ;
   surface_albedo_1560nm:long_name = "surface albedo at 1560nm" ;
```

```
       surface_albedo_1560nm:units = "1" ;
       surface_albedo_1560nm:comment = "Retrieved surface albedo at 1560nm" ;
    float surface_albedo_1630nm(sounding_dim) ;
       surface_albedo_1630nm:long_name = "surface albedo at 1630nm" ;
       surface_albedo_1630nm:units = "1" ;
       surface_albedo_1630nm:comment = "Retrieved surface albedo at 1630nm" ;

// global attributes:
    :title = "ESA CCI SCIAMACHY WFMD XCH4" ;
    :institution = "University of Bremen" ;
    :source = "SCIAMACHY L1B version 7.xx (consolidation W)" ;
    :history = "2015 - product generated with WFMD" ;
    :references = "http://www.esa-ghg-cci.org/\n",
           "http://dx.doi.org/10.5194/acp-11-2863-2011\n",
           "http://dx.doi.org/10.1002/2014EF000265" ;
    :tracking_id = "18283e2f-c973-4ed8-b4c5-20f5ac9b6b0c" ;
    :Conventions = "CF-1.6" ;
    :product_version = "v3.9" ;
    :summary = "Weighting Function Modified DOAS (WFMD) is designed to retrieve column-averaged
            dry air mole fractactions of atmospheric carbon dioxide and methane from the
            near-infrared/shortwave-infrared (NIR/SWIR) nadir spectra of the SCIAMACHY instrument
            onboard ENVISAT." ;
    :keywords = "satellite, ENVISAT, SCIAMACHY, atmosphere, methane" ;
    :id = "ESACCI-GHG-L2-CH4-SCIAMACHY-WFMD-20070701-fv1.nc" ;
    :naming_authority = "iup.uni-bremen.de" ;
    :keywords_vocabulary = "NASA Global Change Master Directory (GCMD)" ;
    :cdm_data_type = "point" ;
    :comment = "These data were produced at the University of Bremen in the framework of the
            ESA GHG-CCI project" ;
    :date_created = "20150427T153724Z" ;
    :creator_name = "University of Bremen, IUP, Oliver Schneising" ;
    :creator_url = "http://www.iup.uni-bremen.de/sciamachy/NIR_NADIR_WFM_DOAS/products/" ;
    :creator_email = "schneising@iup.physik.uni-bremen.de" ;
    :project = "Climate Change Initiative - European Space Agency" ;
    :geospatial_lat_min = -90.f ;
    :geospatial_lat_max = 90.f ;
    :geospatial_lat_units = "degree_north" ;
    :geospatial_lon_min = -180.f ;
    :geospatial_lon_max = 180.f ;
    :geospatial_lon_units = "degree_east" ;
    :geospatial_vertical_min = 0.f ;
    :geospatial_vertical_max = 100000.f ;
    :time_coverage_start = "20070701T000000Z" ;
    :time_coverage_end = "20070701T235959Z" ;
    :time_coverage_duration = "P1D" ;
    :time_coverage_resolution = "P1D" ;
    :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Conventions Version 1.6" ;
    :license = "ESA CCI Data Policy: free and open access" ;
    :platform = "ENVISAT" ;
    :sensor = "SCIAMACHY" ;
    :spatial_resolution = "30km x 60km at nadir (typically)" ;
}
```

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