C3S Greenhouse Gas (GHG:CO2 & CH4) v4.6: Product User Guide and Specification (PUGS)

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History of modifications

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Version	Issue	Date	Description of modification	Chapters / Sections
4.6	1	19-November-2024	New document	All
4.6	2	5-May-2025	Updated following revision of independent reviewers	All
4.6	3	23-May-2025	Further minor corrections following revision by independent reviewers	All

List of datasets covered by this document

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Deliverable ID	Product title	Product type (CDR, ICDR)	Version number	Delivery date
WP1-DDP-GHG-v1	XCO2_OBS4MIPS, XCH4_OBS4MIPS	CDR	4.6	31-Oct-2024

Acronyms

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Acronym	Definition
ATBD	Algorithm Theoretical Basis Document
BESD	Bremen optimal EStimation DOAS
CAR	Climate Assessment Report
C3S	Copernicus Climate Change Service
CCI	Climate Change Initiative
CDR	Climate Data Record
CDS	(Copernicus) Climate Data Store
CMUG	Climate Modelling User Group (of ESA's CCI)
CRG	Climate Research Group
DOAS	Differential Optical Absorption Spectroscopy
ECMWF	European Centre for Medium Range Weather Forecasting
ECV	Essential Climate Variable
EMMA	Ensemble Median Algorithm

ENVISAT	Environmental Satellite (of ESA)
ESA	European Space Agency
ESTOC	European State of the Climate
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCDR	Fundamental Climate Data Record
FoM	Figure of Merit
FP	Full Physics retrieval method
FTIR	Fourier Transform InfraRed
FTS	Fourier Transform Spectrometer
GCOS	Global Climate Observing System
GHG	GreenHouse Gas
GOSAT	Greenhouse Gases Observing Satellite
GOSAT-2	Greenhouse Gases Observing Satellite 2
IPCC	International Panel in Climate Change
IUP	Institute of Environmental Physics (IUP) of the University of Bremen, Germany
JAXA	Japan Aerospace Exploration Agency
L1	Level 1
L2	Level 2
L3	Level 3
L4	Level 4
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Format
NIES	National Institute for Environmental Studies
NIR	Near Infra Red
OBS4MIPS	Observations for Climate Model Intercomparisons
OCFP	OCO-2 Full Physics (FP) algorithm (used by Univ. Leicester)
OCO	Orbiting Carbon Observatory
OCPR	OCO-2 Proxy (PR) algorithm (used by Univ. Leicester)
ODR	Orthogonal Distance Regression
ppb	Parts per billion
ppm	Parts per million
PQAR	Product Quality Assessment Report
PR	(light path) PRoxy retrieval method
PUGS	Product User Guide and Specification
PVIR	Product Validation and Intercomparison Report
RDW	Relative Data Weight
RemoTeC	Retrieval algorithm developed by SRON
SCIAMACHY	SCanning Imaging Absorption spectroMeter for Atmospheric ChartographY
SEOM	Standard Error Of the Mean
SLIM	Simple cLImatological Model for atmospheric CO_2 and CH_4
SRON	SRON Netherlands Institute for Space Research
SRFP	SRON's Full Physics (FP) algorithm (also referred to a RemoTeC FP)
SRPR	SRON's Proxy (PR) algorithm (also referred to a RemoTeC PR)
SWIR	Short Wava Infra Red
TANSO	Thermal And Near infrared Sensor for carbon Observation
TANSO-FTS	Fourier Transform Spectrometer on GOSAT
TANSO-FTS-2	Fourier Transform Spectrometer on GOSAT-2
TCCON	Total Carbon Column Observing Network
TIR	Thermal Infra Red
TR	Target Requirement
TRD	Target Requirements Document
WFM-DOAS (or WFMD)	Weighting Function Modified DOAS
UoL	University of Leicester, United Kingdom
URD	User Requirements Document

WMO	World Meteorological Organization
XGHG	Column-averaged GHG products (here: XCO_2 and XCH_4)

General definitions

Essential climate variable (ECV): An ECV is a physical, chemical, or biological variable or a group of linked variables that critically contributes to the characterization of Earth's climate (Bojinski et al., 2014).

Climate data record (CDR): The US National Research Council (NRC) defines a CDR as a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change (National Research Council, 2004).

Fundamental climate data record (FCDR): A fundamental climate data record (FCDR) is a CDR of calibrated and quality-controlled data designed to allow the generation of homogeneous products that are accurate and stable enough for climate monitoring.

Thematic climate data record (TCDR): A thematic climate data record (TCDR) is a long time series of an essential climate variable (ECV) (Werscheck, 2015).

Intermediate climate data record (ICDR): An intermediate climate data record (ICDR) is a TCDR which undergoes regular and consistent updates (Werscheck, 2015), for example because it is being generated by a satellite sensor in operation.

Satellite data processing levels: The NASA Earth Observing System (EOS) distinguishes six processing levels of satellite data, ranging from Level 0 (L0) to Level 4 (L4) as follows (Parkinson et al., 2006).

L0	Unprocessed instrument data
L1A	Unprocessed instrument data alongside ancillary information
L1B	Data processed to sensor units (geo-located calibrated spectral radiance and solar irradiance)
L2	Derived geophysical variables (e.g., XCO_2) over one orbit
L3	Geophysical variables averaged in time and mapped on a global longitude/latitude horizontal grid
L4	Model output derived by assimilation of observations, or variables derived from multiple measurements (or both)

Absolute systematic error or systematic error: Component of measurement error that in replicate measurements remains constant or varies in a predictable manner. Note that "systematic error" refers to the absolute systematic error (in contrast to "relative systematic error" defined below). For satellite GHG ECV products especially the relative systematic error is important.

Relative systematic error, relative accuracy or relative bias: Identical with "Systematic error" but after bias correction and without considering a possible global offset (overall mean bias). Reflects the importance of spatially and temporally correlated errors (spatio-temporal biases). Computed from standard deviations of spatial and temporal biases.

Bias: Estimate of a systematic measurement error.

Precision: Measure of reproducibility or repeatability of the measurement without reference to an international standard so that precision is a measure of the random and not the systematic error. Suitable averaging of the random error can improve the precision of the measurement but does not establish the systematic error of the observation (CMUG-RBD, 2012).
Note: Precision is quantified with the standard deviation (1-sigma) of the error distribution.

Stability: Term often invoked with respect to long-term records when no absolute standard is available to quantitatively establish the systematic error - the bias defining the time-dependent (or instrument-dependent) difference between the observed quantity and the true value (CMUG-RBD, 2012).
Note: Stability requirements cover inter-annual error changes. If the change in the average bias from one year to another is larger than the defined values, the corresponding product does not meet the stability requirement.

Representativity: Extent to which an average of a set of measured values corresponds to the true average, e.g., over a grid cell. It is important when comparing with or assimilating in models. Measurements are typically averaged over different horizontal and vertical scales compared to model fields. If the measurements are smaller scale than the model it is important. The sampling strategy can also affect this term (CMUG-RBD, 2012).

Threshold requirement: The threshold is the limit at which the observation becomes ineffectual and is not of use for climate-related applications (CMUG-RBD, 2012).

Goal requirement: The goal is an ideal requirement above which further improvements are not necessary (CMUG-RBD, 2012).

Breakthrough requirement: The breakthrough is an intermediate level between the "threshold" and "goal" requirements, which - if achieved - would result in a significant improvement for the targeted application. The breakthrough level may be considered as an optimum, from a cost-benefit point of view when planning or designing observing systems (CMUG-RBD, 2012).

Horizontal resolution: Area over which one value of the variable is representative of (CMUG-RBD, 2012).

Vertical resolution: Height over which one value of the variable is representative of. Only used for profile data (CMUG-RBD, 2012).

Observing Cycle (or **Revisit Time**): Temporal frequency at which the measurements are required (CMUG-RBD, 2012).

XCO_2 (**column-averaged dry-air mole fraction of atmospheric carbon dioxide**): amount of CO_2, expressed in moles, in the vertical column divided by the amount of dry air, also expressed in moles, in that vertical column.

XCH_4 (**column-averaged dry-air mole fraction of atmospheric methane**): amount of CH_4, expressed in moles, in the vertical column divided by the amount of dry air, also expressed in moles, in that vertical column.

Column averaging kernel: The column averaging kernel vertical profile represents the sensitivity of the retrieved XCO_2 or XCH_4 to the true mole fraction depending on altitude. Values near one are ideal and indicate that the influence of the a priori is minimal.

A priori profile: The CO_2 or CH_4 a priori profile represents the knowledge of the vertical profile of the dry-air mole fraction of CO_2 or CH_4 before the measurement. See Rodgers, 2000 for a more detailed explanation.

Observations for Model Intercomparison Project (**Obs4MIPs**, here also **OBS4MIPS**): is an effort to make observational data more accessible for climate model evaluation, development and research. An Obs4MIPs (or OBS4MIPS) dataset is a dataset technically aligned with climate model data, and following data specifications consistent with the CMIP (Coupled Model Intercomparison Project) standard output. See https://pcmdi.github.io/obs4MIPs/ for more detailed information.

Glint observation mode: Viewing geometry used by some satellite instruments where the detector points toward the direction of the specularly reflected sunlight, i.e. the viewing zenith angle and solar zenith angle are approximately equal. This mode is used for measuring CO_2 and CH_4 over water surfaces (such as the ocean), which have low reflectivity in the spectral region used for the retrieval of these gases. By observing in glint mode, the instrument measures a higher reflected radiance compared to other viewing geometries, enhancing the signal for the gas retrievals.

Inter-algorithm spread (**IAS**): Algorithm-to-algorithm standard deviation of the grid box averages (for a set of L3 algorithms). It informs about potential regional or temporal systematic uncertainties.

Mean Local Time (MLT): Expression of time given by the hour angle of the mean position of the Sun, plus an offset of 12 hours.

Executive summary

This document is a Product User Guide and Specification (PUGS) generated in the framework of the Copernicus Climate Change Service (C3S, https://climate.copernicus.eu/). For C3S a large number of satellite-derived Essential Climate Variable (ECV) data products are generated and made available via the Copernicus Climate Data Store (CDS, https://cds.climate.copernicus.eu/).

This document is the user guide for two satellite-derived atmospheric carbon dioxide (CO_2) and methane (CH_4) C3S data products, XCO2_OBS4MIPS and XCH4_OBS4MIPS, respectively. CO_2 and CH_4 are important greenhouse gases (GHG). The two products are column-

averaged dry-air mole fractions of CO_2 and CH_4, denoted as XCO_2 (in parts per million, ppm) and XCH_4 (in parts per billion, ppb), respectively. These two "XGHG" products are generated in C3S project C3S2_313a_DLR led by DLR, Germany (a follow-on activity of project C3S2_312a_Lot2, also led by DLR). In the following this project is referred to as the C3S/GHG project. Within this project also mid-tropospheric CO_2 and CH_4 products are generated. These mid-tropospheric CO_2 and CH_4 products are not described in this document but in dedicated separate documents (ATBD MTGHG, 2024, PQAR MTGHG, 2024 and PUGS MTGHG, 2024).

The XCO2_OBS4MIPS and XCH4_OBS4MIPS products are merged multi-sensor XCO_2 and XCH_4 Level 3 (L3) products with monthly time and 5^ox5^o spatial resolution, generated using an ensemble of individual satellite sensor Level 2 (L2) products. The algorithm that produced these products has been developed at the University of Bremen, Germany, and has also been used in the past to generated previous versions of these products (e.g. ATBD XGHG main, 2023, PQAR XGHG main, 2023, PUGS XGHG main, 2023).

The two XGHG data products are generated - or have been generated in the past - from XCO_2 and XCH_4 products from the satellite instruments SCIAMACHY onboard ENVISAT (Burrows et al., 1995; Bovensmann et al., 1999), TANSO-FTS/GOSAT (Kuze et al., 2009, 2016), TANSO-FTS-2/GOSAT-2 (Suto et al., 2021). For product XCO2_OBS4MIPS also L2 products from NASA's OCO-2 mission (Crisp et al., 2004; Boesch et al., 2011) have been used as input products.

Both the input data and the algorithm used to generate the product are described in detail in ATBD XGHG, 2024.

1. Product Description(s)

In this section an overview of the version 4.6 XCO2_OBS4MIPS and XCH4_OBS4MIPS data products- specified in terms of variable, its property, processing levels and instruments - is given.

Carbon dioxide and methane are so-called Essential Climate Variables (ECVs) and the need to monitor them has been clearly identified, including the definition of key requirements (TRD GAD GHG, 2024; ESA-CCI-GHG-URD, 2024; CMUG-RBD, 2012; GCOS-245; GCOS-200; GCOS-195; GCOS-154). In recent years several satellite-derived ECV data products, including CO_2 and CH_4 (e.g., Buchwitz et al., 2013a, 2016, 2017; Reuter et al., 2013, 2020; Schneising et al., 2023), have been generated in particular in the framework of the Climate Change Initiative (CCI) of ESA (European Space Agency) (e.g., Hollmann et al., 2013) and operationally via C3S.

Previous versions of these satellite-derived CO_2 and CH_4 data products have been used for several (primarily scientific) applications, e.g.,

- to improve our knowledge on the various natural and anthropogenic (surface) sources and sinks of these important greenhouse gases (GHG) (see, e.g., Alexe et al., 2015; Bergamaschi et al., 2015; Chevallier et al., 2014, 2016; Cressot et al., 2014; Detmers et al., 2015; Guerlet et al., 2013; Houweling et al., 2015; McNorton et al., 2016; Pandey et al., 2016; Reuter et al., 2014b, 2017; Schneising et al., 2014b, 2020; Turner et al., 2015, 2016, and references given therein),
- to monitor the global or regional distribution of CO_2 and CH_4 (e.g., Buchwitz et al., 2007, 2016b; Schneising et al., 2011; Frankenberg et al., 2011; Massart et al., 2016; Reuter et al., 2020; Hachmeister et al., 2022, 2024),
- to improve our knowledge on emission ratios, e.g., for biomass burning (e.g., Ross et al., 2013; Parker et al., 2016), and
- for comparisons with (chemistry) climate models (e.g., Shindell et al., 2013; Hayman et al., 2014; Lauer et al., 2017; Gier et al., 2020) and other models (e.g., Schneising et al., 2014a; Parker et al., 2016).

The data products presented here have been derived from satellite radiances in the Near Infrared / Short Wave Infrared (NIR/SWIR) spectral region using data from the following sensors: SCIAMACHY/ENVISAT, TANSO-FTS/GOSAT, TANSO-FTS-2/GOSAT-2 and OCO-2. Satellite radiance observations in the NIR/SWIR spectral region in downward-looking observation modes are sensitive to atmospheric CO_2 and CH_4 concentration changes with good sensitivity down to the Earth's surface (because solar radiation reflected at the Earth's surface is observed). These measurements permit to retrieve "total column information" but do not permit to retrieve (detailed) information on the vertical profiles of CO_2 and CH_4.

Figure 1 provides an overview of the satellites sensors used to generate the XCO_2 and XCH_4 products. All sensors permit the retrieval of XCO_2 and XCH_4 with the exception of OCO-2, which only permits the retrieval of XCO_2.

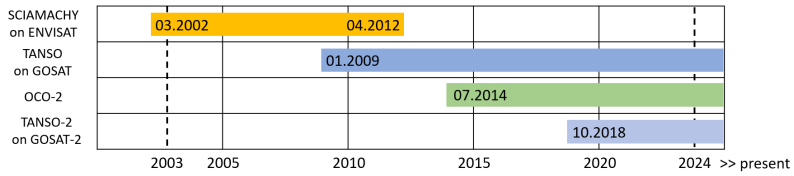

Figure 1: Satellite sensor time coverage. All sensors permit the retrieval of XCO_2 and XCH_4 with the exception of OCO-2 (XCO_2 only).

The input Level 2 (L2) data products are satellite-derived column-averaged dry-air mole fractions of CO_2 and CH_4, denoted XCO_2 (in parts per million, ppm) and XCH_4 (in parts per billion, ppb).

The Level 3 (L3) data products generated from the merged individual L2 data products are in OBS4MIPS format and described in detail in Section 1.1 for XCO_2 and in Section 1.2 for XCH_4. OBS4MIPS (Observations for Model Intercomparisons Project https://pcmdi.github.io/obs4MIPs/ with last access: 2-Apr-2025) is an activity to make observational products more accessible especially for climate model intercomparisons.

The XCO_2 and XCH_4 OBS4MIPS products are gridded data products in NetCDF format with a spatial resolution of 5^ox5^o (i.e., using an equirectangular (Cartesian) latitude/longitude grid) and a monthly time resolution. These products have been generated using as input the L2 EMMA (Ensemble Median Algorithm) v4.6 products (see ATBD XGHG, 2024).

The EMMA algorithm takes the input L2 data products and merges them into a new L2 product. It is this new EMMA L2 dataset that is then gridded to produce the OBS4MIPS products.

The EMMA algorithm and its input data are described in detail in ATBD XGHG, 2024. In broad terms, the merging algorithm grids all L2 products to a monthly 10^o x 10^o grid and selects, for each grid cell, the L2 product that corresponds to the median of the gridded input products. The output of EMMA is a merged L2 intermediate product that contains the soundings of the individual L2 input products that were selected from the merging algorithm, i.e. for each grid cell, one algorithm is selected, and the L2 soundings corresponding to this algorithm become part of the merged L2 product.

The individual input L2 data products are bias corrected. Bias correction is usually an integral part of the L2 products and described in the corresponding literature. When merging the L2 products with EMMA, they are harmonized by adjusting them to a common a priori and by applying a global offset correction. However, no additional bias correction has been applied to the two OBS4MIPS products.

For the EMMA algorithm, also SLIM (Simple cLImatological Model for atmospheric CO_2 and CH_4 (Noël et al., 2022). and TCCON (Total Carbon Column Observing Network, Wunch et al., 2011) GGG2020 (Laughner et al., 2024) data are used. The SLIM data is used both as a new common a priori as well as to make a global offset correction. The TCCON data are essentially used to calibrate the reported uncertainties of the input L2 products and for the validation.

Table 1 lists the XCO_2 and XCH_4 data products presented in this document. These two products are merged multi-sensor XCO_2 and XCH_4 L3 products with monthly time and 5^ox5^o spatial resolution generated using an ensemble of individual satellite sensor L2 products. The algorithm has been developed at the University of Bremen, Germany, and has also been used in the past to generated previous versions of these products (e.g., Reuter et al., 2013, 2020).

Table 1: Overview XCO_2 and XCH_4 OBS4MIPS data products. The sensors used for the input L2 products are listed in the second column. The third column shows the product version numbers, dates and periods covered by the products, and the dates in which each of the products has become available in the Copernicus Climate Data Store.

Product ID	Sensor(s)	Product version: Availability: Temporal coverage	Comments
XCO2_OBS4MIPS	Merged SCIAMACHY, GOSAT, GOSAT-2, OCO-2	v4.6: Dec. 2024: 01/2003-12/2023	Merged L3 XCO_2 product in OBS4MIPS format. Temporal resolution: monthly Spatial resolution: 5^ox5^o
XCH4_OBS4MIPS	Merged SCIAMACHY, GOSAT, GOSAT-2	v4.6: Dec. 2024: 01/2003-12/2023	Merged L3 XCH_4 product in OBS4MIPS format. Temporal resolution: monthly Spatial resolution: 5^ox5^o

We recommend users of these L3 products to read the relevant peer-reviewed publications, i.e., Reuter et al., 2020, describing how (a previous version of) this data product has been generated and how it can be used to address scientific applications.

The L2 data used as input to generate the XCO2_OBS4MIPS and XCH4_OBS4MIPS products is described in Section 2.2 of ATBD XGHG, 2024. Two additional datasets are used: in order to account for different column averaging kernels, all L2 retrieval results are adjusted to a common a priori, namely the SLIM. Scaling of the reported L2 uncertainties and validation are done with TCCON as reference data set. See ATBD XGHG, 2024 for a more detailed explanation.

1.1. OBS4MIPS XCO_2 description

The main quantity / data field of this product is the column-average dry-air mole fraction of atmospheric carbon dioxide (CO_2), denoted as XCO_2. XCO_2 in these products is a dimensionless quantity (unit: mol/mol) defined as the vertical column of CO_2 divided by the vertical column of dry air (= all air molecules except water vapor) (see, e.g., Buchwitz et al., 2005, for details).

The input data to generate the OBS4MIPS XCO_2 product is illustrated in Figure 6 in ATBD XGHG, 2024. For more detailed information on the input data and the processing algorithm see the ATBD XGHG, 2024 document.

In this section, version v4.6 of the XCO2_OBS4MIPS product is described. Table 2 shows a summary of the history of changes in previously generated XCO2_OBS4MIPS datasets.

Table 2: History of changes in previously generated XCO2_OBS4MIPS datasets. The first column contains the Climate Data Record (CDR) number, the second column, the product version and date of its delivery. The third column list the used input data to generate the given datasets. The fourth column summarizes the changes with respect to the previous version.

CDR number	Product version (delivery date)	Input data	Remarks
CDR8	v4.6. (09.08.2024)	**L2 input data:** SCIAMACHY BESD v02.01.02, GOSAT NIES v03.05BC, GOSAT RemoteC v2.3.8, GOSAT UOL-FP v7.3, GOSAT ACOS v9r, GOSAT FOCAL v3.0, OCO-2 NASA v11.1, OCO-2 FOCAL v11, GOSAT2 NIES v02.00, GOSAT-2 RemoteC v2.1.0, GOSAT-2 FOCAL v3.0 **Common a priori:** SLIM2024 **Validation data:** TCCON GGG2020	New retrieval versions, new common a priori, extended time period.
CDR7	v4.5. (05.08.2023)	**L2 input data:** SCIAMACHY BESD v02.01.02, GOSAT NIES v02.9xBC, GOSAT RemoteC v2.3.8, GOSAT UOL-FP v7.3, GOSAT ACOS v9r, GOSAT FOCAL v3.0, OCO-2 NASA v11.1, OCO-2 FOCAL v10.1, GOSAT2 NIES v02.00, GOSAT-2 RemoteC v2.0.0, GOSAT-2 FOCAL v3.0 **Common a priori:** SLIM2023 **Validation data:** TCCON GGG2020	New retrieval versions, new common a priori, extended time period, new validation data.
CDR6	v4.4. (10.07.2022)	**L2 input data:** SCIAMACHY BESD v02.01.02, GOSAT NIES v02.9xBC, GOSAT RemoteC v2.3.8, GOSAT UOL-FP v7.3, GOSAT ACOS v9r, GOSAT FOCAL v3.0, OCO-2 NASA v10.2, OCO-2 FOCAL v10, GOSAT-2 RemoteC v2.0.0, GOSAT-2 FOCAL v3.0 **Common a priori:** SLIM2022 **Validation data:** TCCON GGG2014	New retrieval versions, new common a priori, extended time period, added GOSAT-2 data, bug fixes, code optimizations.
CDR5	v4.3. (05.02.2021)	**L2 input data:** SCIAMACHY BESD v02.01.02, GOSAT ACOS v9r, GOSAT FOCAL v1.0, GOSAT RemoteC v2.3.8, GOSAT UOL-FP v7.3, GOSAT NIES v02.9xBC, GOSAT PPDF-S v02, OCO-2 NASA v10.2, OCO-2 FOCAL v09 **Common a priori:** SC2C2020 **Validation data:** TCCON GGG2014	New retrieval versions, new common a priori, extended time period, bug fixes in the computations of the averaging kernels (with minimal impact), rejection of non-unique RemoTeC soundings.
CDR4	v4.2. (28.07.2020)	**L2 input data:** SCIAMACHY BESD v02.01.02, GOSAT ACOS v9r, GOSAT FOCAL v1.0, GOSAT RemoteC v2.3.8, GOSAT UOL-FP v7.3, GOSAT NIES v02.75BC, GOSAT PPDF-S v02, OCO-2 NASA v10.2, OCO-2 FOCAL v09 **Common a priori:** SC2C2020 **Validation data:** TCCON GGG2014	New retrieval versions, new common a priori, extended time period.
CDR3	v4.1. (02.07.2019)	**L2 input data:** SCIAMACHY BESD v02.01.02, GOSAT ACOS v7.3.10a, GOSAT NIES v02.75BC, GOSAT PPDF-S v02, GOSAT RemoteC v2.3.8, GOSAT UOL-FP v7.2, OCO-2 FOCAL v08, OCO-2 NASA v9.0.03 **Common a priori:** SECM2018	New retrieval versions, extended time period.

		Validation data: TCCON GGG2014	
CDR2	v3.1. (03.09.2018)	**L2 input data:** SCIAMACHY BESD v02.01.02, GOSAT ACOS v7.3.10a, GOSAT NIES v02.72, GOSAT NIES v02BC, GOSAT PPDF-S v02, GOSAT RemoteC v2.3.8, GOSAT UOL-FP v7.2 **Common a priori:** SECM2018 **Validation data:** TCCON GGG2014	New retrieval versions, new common a priori, extended time period, re-structured code.
CDR1	v3.0. (18.08.2017)	**L2 input data:** SCIAMACHY BESD v02.01.02, GOSAT ACOS v7.3.10a, GOSAT NIES v02, GOSAT RemoteC v2.3.8, GOSAT UOL-FP v7.1 **Common a priori:** SECM2016 **Validation data:** TCCON GGG2014	First EMMA CO2 version operationally processed in the frame of C3S.

1.2. OBS4MIPS XCH_4 description

The main quantity / data field of this product is the column-average dry-air mole fraction of atmospheric methane (CH_4). XCH_4 is a dimensionless quantity (unit: mol/mol) defined as the vertical column of CH_4 divided by the vertical column of dry air (= all air molecules except water vapor) (see, e.g., Buchwitz et al., 2005, for details).

The input data to generate the OBS4MIPS XCO_4 product is illustrated in Figure 7 in ATBD XGHG, 2024. For more detailed information on the input data and the processing algorithm see the ATBD XGHG, 2024 document.

In this section, version v4.6 of the XCH4_OBS4MIPS product is described. Table 3 shows a summary of the history of changes in previously generated XCH4_OBS4MIPS datasets.

Table 3: History of changes in previously generated XCH4_OBS4MIPS datasets. The first column contains the Climate Data Record (CDR) number, the second column, the product version and date of its delivery. The third column list the used input data to generate the given datasets. The fourth column summarizes the changes with respect to the previous version.

CDR number	Product version (delivery date)	Input data	Remarks
CDR8	v4.6. (09.08.2024)	**L2 input data:** SCIAMACHY WFMD v4.0, GOSAT FOCAL-FP v3.0, GOSAT FOCAL-PR v3.0, GOSAT NIES v03.05BC, GOSAT RemoteC-FP v2.3.8, GOSAT RemoteC-PR v2.3.9, GOSAT UOL-FP v7.3, GOSAT UOL-PR v9.0, GOSAT2 FOCAL-FP v3.0, GOSAT2 FOCAL-PR v3.0, GOSAT RemoteC-FP v2.1.0, GOSAT RemoteC-PR v2.1.0, GOSAT2 NIES v02.00 **Common a priori:** SLIM2024 **Validation data:** TCCON GGG2020	New retrieval versions, new common a priori, extended time period.
CDR7	v4.5. (05.08.2023)	**L2 input data:** SCIAMACHY WFMD v4.0, GOSAT FOCAL-FP v3.0, GOSAT FOCAL-PR v3.0, GOSAT NIES v02.9xBC, GOSAT RemoteC-FP v2.3.8, GOSAT RemoteC-PR v2.3.9, GOSAT UOL-FP v7.3, GOSAT UOL-PR v9.0, GOSAT-2 FOCAL-FP v3.0, GOSAT-2 FOCAL-PR v3.0, GOSAT RemoteC-FP v2.0.0, GOSAT RemoteC-PR v2.0.1, GOSAT-2 NIES v02.00 **Common a priori:** SLIM2023 **Validation data:** TCCON GGG2020	New retrieval versions, new common a priori, extended time period, new validation data.
CDR6	v4.4. (19.07.2022)	**L2 input data:** SCIAMACHY WFMD v4.0, GOSAT FOCAL-FP v3.0, GOSAT FOCAL-PR v3.0, GOSAT NIES v02.9xBC, GOSAT RemoteC-FP v2.3.8, GOSAT RemoteC-PR v2.3.9, GOSAT UOL-FP v7.3, GOSAT UOL-PR v9.0, GOSAT-2 FOCAL-FP v3.0, GOSAT-2 FOCAL-PR v3.0, GOSAT RemoteC-FP v2.0.0, GOSAT RemoteC-PR v2.0.0, GOSAT-2 NIES v01.07 **Common a priori:** SLIM2022 **Validation data:** TCCON GGG2014	New retrieval versions, new common a priori, extended time period, *added* GOSAT-2 data, bug fixes, code optimizations.
CDR5	v4.3. (05.02.2021)	**L2 input data:** SCIAMACHY WFMD v4.0, GOSAT RemoteC-FP v2.3.8, GOSAT RemoteC-PR v2.3.9, GOSAT UOL-FP v7.3, GOSAT UOL-PR v9.0, GOSAT NIES v02.9xBC, GOSAT PPDF-S v02 **Common a priori:** SC2C2020 **Validation data:** TCCON GGG2014	New retrieval versions, new common a priori, extended time period, bug fixes in AK computations (with tiny impact), rejection of non-unique RemoTeC soundings.
CDR4	v4.2. (30.07.2020)	**L2 input data:** SCIAMACHY WFMD v4.0, GOSAT RemoteC-FP v2.3.8, GOSAT RemoteC-PR v2.3.9, GOSAT UOL-FP v7.3, GOSAT UOL-PR v9.0, GOSAT NIES v02.75BC, GOSAT PPDF-S v02 **Common a priori:** SC2C2020 **Validation data:** TCCON GGG2014	New retrieval versions, new common a priori, extended time period.
CDR3	v4.1. (03.07.2019)	**L2 input data:** SCIAMACHY WFMD v4.0, GOSAT RemoteC-FP v2.3.8, GOSAT RemoteC-PR v2.3.9, GOSAT UOL-FP v7.2, GOSAT UOL-PR v7.2, GOSAT NIES v02.75BC, GOSAT PPDF-S v02 **Common a priori:** SECM2018 **Validation data:** TCCON GGG2014	New retrieval versions, extended time period.
CDR2	v3.1. (12.09.2018)	**L2 input data:** SCIAMACHY WFMD v4.0, GOSAT RemoteC-FP v2.3.8, GOSAT RemoteC-PR v2.3.8, GOSAT UOL-FP v7.2, GOSAT UOL-PR v7.2, GOSAT NIES v02BC, GOSAT PPDF-S v02, GOSAT NIES v02.72 **Common a priori:** SECM2018 **Validation data:** TCCON GGG2014	New retrieval versions, new common a priori, extendet time period, re-structured code.
CDR1	v3.0. (18.08.2017)	**L2 input data:** SCIAMACHY WFMD v4.0, GOSAT RemoteC-FP v2.3.8, GOSAT RemoteC-PR v2.3.8, GOSAT UOL-FP v7.1, GOSAT UOL-PR v7.0, GOSAT NIES v02 **Common a priori:** SECM2016 **Validation data:** TCCON GGG2014	First EMMA CH4 version operationally processed in the frame of C3S.

1.3. Overview of Product Target Requirements

Target requirements are described in the Target Requirements and Gap Analysis document (TR-GAD GHG, 2024).

Table 4 compares the required and the achieved performance for random error (precision), required accuracy (in terms of spatio-temporal biases) and stability (in terms of linear bias drift). The data quality level is also summarized below (see Section 1.3 of PQAR XGHG, 2024 for a more detailed explanation on the reported probabilities).

Table 4: Compliance with User Requirements. XCO2 and XCH4 random ("precision"), systematic error and stability requirements (from TR-GAD GHG, 2024). Abbreviations: G=Goal, B=Breakthrough, T=Threshold requirement. §) Required systematic error after an empirical bias correction that does not use the verification data. #) Required systematic error and stability after bias correction, where bias correction is not limited to the application of a constant offset / scaling factor.

Parameter	Requirement type	Requirement			Reported value	Probability that met
		G	B	T		
CO_2	**Random error (precision) (1000^2 km^2 monthly) (ppm)**	< 0.3	**< 1.0**	< 1.3	0.91 (<= **1.0**, within Breakthrough)	-
	Accuracy: Relative systematic error (ppm)	< 0.2 (absolute)	< 0.3 (relative§))	**< 0.5** (relative#))	0.4 (<= **0.5**, within Threshold)	77%
	Stability: Linear bias trend (ppm/year)	**< 0.2** (absolute)	< 0.3 (relative§))	< 0.5 (relative#))	0.02 (<= 0.2, within Goal)	97%
CH_4	**Random error (precision) (1000^2 km^2 monthly) (ppb)**	< 3	< 5	**< 11**	6.1 (<= **11**, within Threshold)	-
	Accuracy: Relative systematic error (ppb)	< 1 (absolute)	< 5 (relative§))	**< 10** (relative#))	6.25 (<= **10**, within Threshold)	84%
	Stability: Linear bias trend (ppb/year)	**< 1** (absolute)	< 2 (relative§))	< 3 (relative#))	0.32 (<=1, within Goal)	97%

The validation of Level 3 product XCO2_OBS4MIPS can be summarized as follows:

- The overall monthly mean uncertainty is 0.91 ppm and the mean bias is 0.34 ppm. Relative systematic error, i.e., the spatio-temporal bias, is 0.4 ppm (1-sigma). The computed linear drift of 0.02±0.12 ppm/year (1-sigma) is small and not significant.
- The probability that the 0.5 ppm accuracy requirement is met is 77%.
- The probability that the 0.5 ppm/year stability requirement is met is 97%.
- Overall, this product has therefore reasonable accuracy and high stability.

The validation of Level 3 product XCH4_OBS4MIPS can be summarized as follows:

- The overall monthly mean uncertainty is 6.1 ppb and the mean bias is -0.63 ppb. Relative systematic error, i.e., the spatio-temporal bias, is 6.25 ppb (1-sigma). The computed linear drift of 0.32±0.87 ppb/year (1-sigma) is small and not significant.
- The probability that the 10 ppb accuracy requirement is met is 84%.
- The probability that the 3 ppb/year stability requirement is met is 97%.
- Overall, this product has therefore very good accuracy and high stability.

1.4. Example visualization of key variables

Figure 2 shows an example of XCO_2 (top) and XCH_4 (bottom) for August 2015 as well as the corresponding total uncertainty.

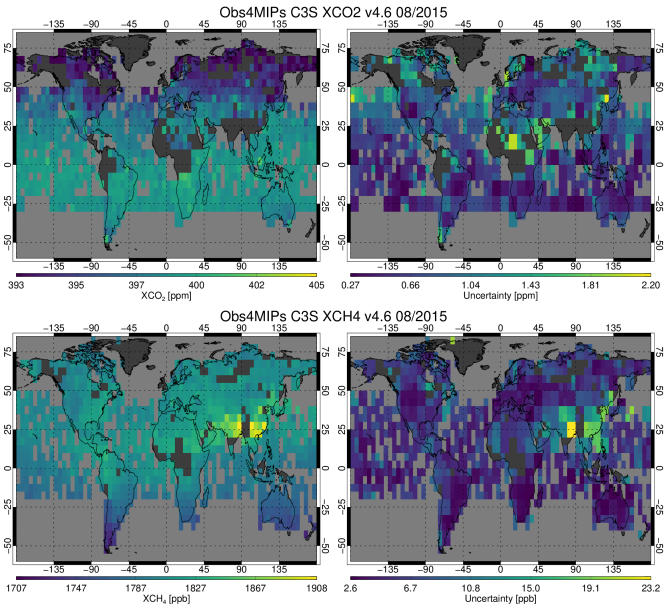

Figure 2: Top: XCO2_OBS4MIPS for August 2015 (left) and its uncertainty (right) computed from the retrieval noise and EMMA's inter-algorithm spread. Gray areas indicate the absence of data (light gray = ocean, dark gray = land). Bottom: Same for XCH4_OBS4MIPS.

Another example of XCO_2 (top) and XCH_4 (bottom) for April 2015 as well as the corresponding total uncertainty is shown in Figure 3.

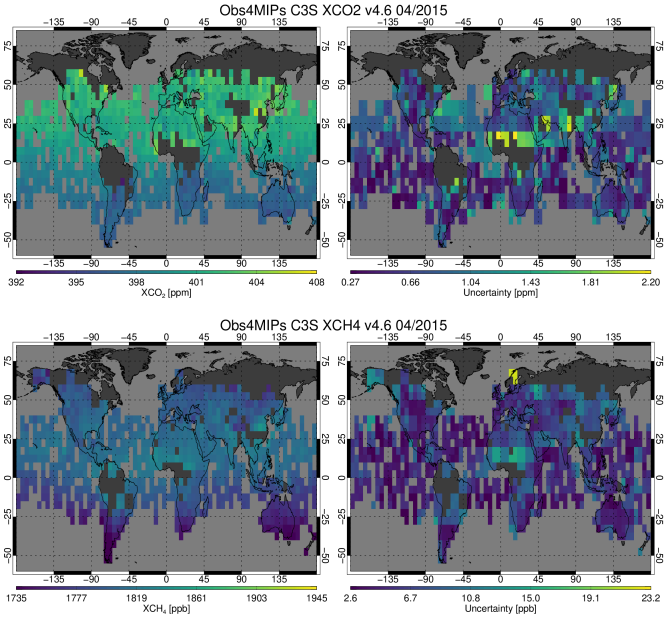

Figure 3: Top: XCO2_OBS4MIPS for April 2015 (left) and its uncertainty (right) computed from the retrieval noise and EMMA's inter-algorithm spread. Gray areas indicate the absence of data (light gray = ocean, dark gray = land). Bottom: Same for XCH4_OBS4MIPS.

A XCO_2 value of, for example, 400 ppm at a given location means that 400 CO_2 molecules are present in the atmosphere above that location per one million air molecules excluding water molecules. XCO_2 can be retrieved from instruments such as SCIAMACHY/ENVISAT and TANSO-FTS/GOSAT using Optimal Estimation (Rodgers, 2000) or DOAS (Buchwitz et al., 2000) retrieval algorithms as shown in various publications (e.g., Buchwitz et al., 2005; Butz et al., 2011; Cogan et al., 2012; Noël et al., 2021, 2022; Reuter et al., 2011; 2013; Schneising et al., 2011; Yoshida et al., 2013). These products have been validated using ground-based Total Carbon Column Observing Network (TCCON) (Wunch et al., 2010, 2011, 2015, Laughner et al., 2024) XCO_2 observations (e.g., Dils et al., 2014).

A XCH_4 value of, for example, 1800 ppb at a given location means that 1800 CH_4 molecules are present in the atmosphere above that location per one billion air molecules excluding water molecules. XCH_4 can be retrieved from instruments such as SCIAMACHY/ENVISAT and TANSO-FTS/GOSAT using Optimal Estimation (Rodgers, 2000) or DOAS (Buchwitz et al., 2000) retrieval algorithms as shown in various publications (e.g., Buchwitz et al., 2005; Butz et al., 2011; Frankenberg et al., 2011; Schneising et al., 2011, 2023; Noël et al., 2022; Parker et al., 2011; Schepers et al., 2012; Yoshida et al., 2013). These products have been validated using ground-based TCCON (Wunch et al., 2010, 2011, 2015, Laughner et al., 2024) XCH_4 observations (e.g., Dils et al., 2014).

Figure 4 shows as XCO_2 time series for the northern (red) and southern (blue) hemisphere averages. The curves in the figure show some known features of atmospheric CO_2, such as a continuous increase in its yearly concentration, which results mainly from anthropogenic emissions due to the combustion of fossil fuels. Another feature that we can appreciate in the figure is the seasonality of atmospheric CO_2, with peaks in its concentration at the beginning of the vegetation growing season and a decrease in its concentration as the CO_2 uptake by plants starts to increase. The atmospheric CO_2 concentration increases again when the photosynthetic activity starts to decrease at the end of the summer. The oscillations in the CO_2 concentration are more pronounced in the northern hemisphere because of the higher amount of vegetation in this hemisphere compared to the southern hemisphere.

Figure 5 shows a similar plot for XCH_4. The curves shown in Figure 5 show as well a continuous increase of atmospheric CH_4. Its seasonal cycle is the result of the seasonality of its sources (like wetlands, rice paddies or biomass burning) and sinks (reaction with the hydroxyl radical), which are driven by meteorological conditions (e.g. Dowd et al., 2023). A large uncertainty can be observed in the methane product for the time period until 2009, in which there is only data from SCIAMACHY. The reason for the large uncertainty in this period is a technical problem in important methane-sensitive detector pixels of the SCIAMACHY instrument.

The higher values of XCH_4 in the northern hemisphere compared to the southern hemisphere is clearly visible for XCH_4 (Figure 5), and less pronounced for XCO_2 (Figure 4). This results from higher emissions of both CO_2 and CH_4 in the northern hemisphere.

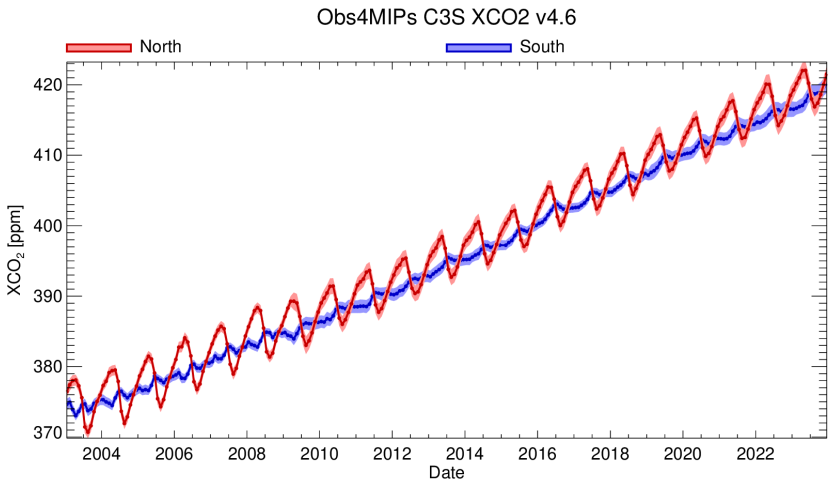

Figure 4: C3S XCO_2 time series (product XCO2_OBS4MIPS version 4.6) for the northern (red) and southern (blue) hemispheres. The shaded areas show the corresponding uncertainty consisting of (calibrated) measurement noise and inter-algorithm-spread.

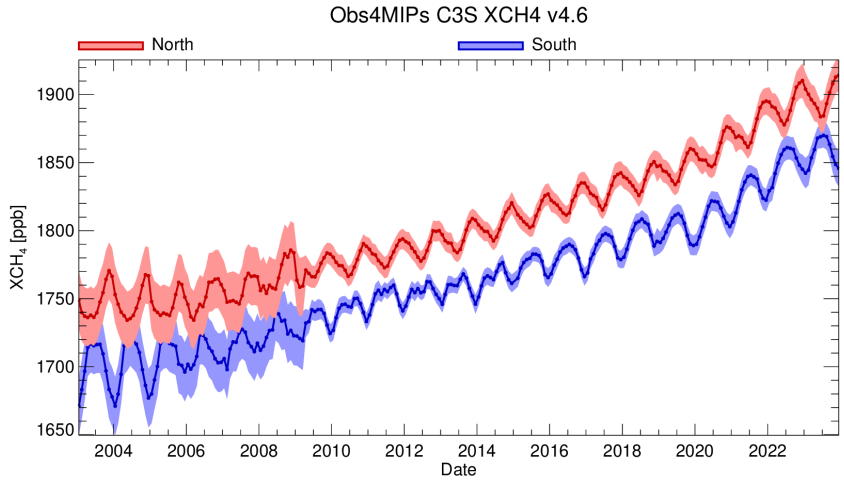

Figure 5: C3S XCH_4 time series (product XCH4_OBS4MIPS version 4.6) for the northern (red) and southern (blue) hemispheres. The shaded areas show the corresponding uncertainty consisting of (calibrated) measurement noise and inter-algorithm-spread.

1.5. Data usage information

The main quantity / data field is the column-average dry-air mole fraction of atmospheric carbon dioxide (CO_2), denoted as XCO_2, for the XCO2_OBS4MIPS product. The column-average dry-air mole fraction of atmospheric of methane (CH_4), denoted as XCH_4, is the main quantity / data field of the XCH4_OBS4MIPS product. We collectively refer to XCO_2 and XCH_4 as XGHG.

In contrast to the most L2 products, in which the units used are ppm (10^{-6}) or ppb (10^{-9}), in these products, XCO_2 and XCH_4 are reported in units of mol/mol, defined as the vertical column of CO_2 or CH_4 divided by the vertical column of dry air (= all air molecules except water vapor) (see, e.g., Buchwitz et al., 2005, for details), reported as numerical fractional values in the range 0.0 – 1.0. For example, a XCO_2 value of 0.000400 corresponds to 400 ppm (parts per million); a XCH4 value of 0.000001800 corresponds to 1800 ppb (parts per billion).

Also reported (in the same units) are the corresponding (1-sigma) uncertainties (variables xco2_stderr and xch4_stderr).

These variables are reported per month and per $5^{o}x5^{o}$ (latitude times longitude) grid cell.

Also provided are variables related to spatial (variables lat, lat_bnds, lon, lon_bnds) and temporal information (time, time_bnds) as described in detail in Section1.5.3. Information on altitude sensitivity (variable column_averaging_kernel) and *a priori* profiles (variables vmr_profile_co2_apriori and vmr_profile_ch4_apriori) is also provided.

1.5.1. Data format and file naming

Each of the products (XCO2_OBS4MIPS and XCH4_OBS4MIPS) is contained in a single file using this file name convention: *xghg_c3s_l3_v46_YYYYMM_YYYYMM.nc*.

Explanation:

- *xghg*: Variable name (xco2 or xh4)
- *c3s*: Copernicus Climate Change Service
- *l3*: Level 3 product
- *v46*: Version 4.6
- *YYYYMM_YYYYMM:* First month and year and last month and year of data set.

For example, the product named *xco2_c3s_l3_v46_200301_202312.nc* refers to the L3 XCO2_OBS4MIPS product in its version 4.6, which covers the period from January 2003 to December 2023.

1.5.2. Quality flags and data masks

The products contain no quality flags. Missing data is marked for each variable as described in Section 1.5.3.

Data masking is typically not required but users have the option to use, for example, only data over land using variable “land_fraction”.

1.5.3. File contents

Table 5 and Table 6 list the main characteristics of the XCO2_OBS4MIPS and XCH4_OBS4MIPS products, respectively. See ATBD XGHG, 2024, for an overview of how these products have been generated and for additional details.

Table 5: Main characteristics of the XCO_2 OBS4MIPs v4.6 product.

CF variable name, units	Long name: column-average dry-air mole fraction of atmospheric carbon dioxide or Standard name: dry_atmosphere_mole_fraction_of_carbon_dioxide Units: dimensionless (mol/mol) See also: CF Standard Name Table, Version 31, 08 March 2016 (http://cfconventions.org/Data/cf-standard-names/31/build/cf-standard-name-table.html)
Spatial resolution	5° equal angle
Temporal resolution	Monthly average, from January 2003 – December 2023
Coverage	Global (2003 – mid 2009: land only; afterwards land and ocean)

Table 6: Main characteristics of the XCH4 OBS4MIPs v4.6 product.

CF variable name, units	Long name: column-average dry-air mole fraction of atmospheric methane Standard name: dry_atmosphere_mole_fraction_of_methane Units: dimensionless (mol/mol) See also: CF Standard Name Table, Version 31, 08 March 2016 (http://cfconventions.org/Data/cf-standard-names/31/build/cf-standard-name-table.html)
Spatial resolution	5° equal angle
Temporal resolution	Monthly average, from January 2003 – December 2023

CF variable name, units	Long name: column-average dry-air mole fraction of atmospheric methane Standard name: dry_atmosphere_mole_fraction_of_methane Units: dimensionless (mol/mol) See also: CF Standard Name Table, Version 31, 08 March 2016 (http://cfconventions.org/Data/cf-standard-names/31/build/cf-standard-name-table.html)
Coverage	Global (November 2005 – March 2009: land only; before and afterwards land and ocean)

Note that a resolution of 5°x5° has been selected (instead of, e.g., 1°x1°) to ensure better noise suppression (note that the underlying individual satellite retrievals are noisy and sparse due to very strict quality filtering) (see ATBD XGHG, 2024).

Each of the OBS4MIPS L3 products includes the variables listed in Table 7. They are described in the following.

Table 7: OBS4MIPS variables. x, y, z, t, represent the number of grid points in longitude, latitude, pressure, and temporal dimension respectively.

Name	Type	Dimension	Units	Short Description
time	Float	t	Days since 1990-01-01	Time center
time_bnds	Float	t,2	Days since 1990-01-01	Time boundaries
lat	Float	y	Degrees north	Latitude center
lat_bnds	Float	y,2	Degrees north	Latitude boundaries
lon	Float	x	Degrees east	Longitude center
lon_bnds	Float	x,2	Degrees east	Longitude boundaries
pre	Float	z	Surface pressure	Pressure center
pre_bnds	Float	z,2	Surface pressure	Pressure boundaries
land_fraction	Float	x,y	1	Land area fraction
xghg	Float	x,y,t	1	Satellite retrieved column-average dry-air mole fraction of CO_2 or CH_4
xghg_nobs	Integer	x,y,t	1	Number of individual L2 observations
xghg_stdder	Float	x,y,t	1	Standard error
xghg_stddev	Float	x,y,t	1	Standard deviation
column_averaging_kernel	Float	x,y,z,t	1	Column-averaging kernel
vmr_profile_ghg_apriori	Float	x,y,z,t	1	A priori dry-air mole fraction profile

*The name <*ghg*> stands for *co2* for the XCO2_OBS4MIPS product and for ch4 for the XCH4_OBS4MIPS product. E.g. the variable *xghg* in this table is named *xco2* in the XCO2_OBS4MIPS product and *xch4* in the XCH4_OBS4MIPS product. Analogously, *xghg_nobs* stands for *xco2_nobs* or *vmr_profile_ghg_apriori* for *vmr_profile_co2_apriori* in XCO2_OBS4MIPS, and *xch4_nobs* or *vmr_profile_ch4_apriori* in XCH4_OBS4MIPS.

Description of each parameter:

time: Time center in days since 1990-01-01.

time_bnds: Time boundaries. Start and end time of each month in days since 1-Jan-1990

lat: Latitude center in degrees north (from -90.0° to +90.0°).

lat_bnds: Latitude boundaries (upper and lower boundaries of 5° latitude bands) in degrees north.

lon: Longitude center in degrees east (from -180.0° to +180.0°).

lon_bnds: Longitude boundaries (upper and lower boundaries of 5° longitude bands) in degrees east.

pre: Pressure level center, dimensionless as normalized to surface pressure.

pre_bnds: Pressure layer boundaries, dimensionless as normalized to surface pressure.

land_fraction: Fraction of 5° x 5° cells covered by land (numerical values are between 0.0 and 1.0). It is computed from GTOPO30 data available from the U.S. Geological Survey.

xghg = {xco2 or xch4}: Main parameter: satellite retrieved column-average dry-air mole fraction of CO_2 or CH_4, respectively. Typical values are << 1.0 (typically close to 0.0004 for XCO_2 and close to 0.0000018 for XCH_4) and 1.0E20 = no data.

xghg_nobs = {xco2_nobs or xch4_nobs}: Number of individual XGHG L2 observations per grid box used to compute the reported L3 XGHG monthly average value (0 = no data).

xghg_stdder = {xco2_stdder or xch4_stdder}: Standard error of the average computed from the single sounding noise and potential seasonal and regional biases, i.e., the inter algorithm spread.

xghg_stddev = {xco2_stddev or xch4_stddev}: Standard deviation of the L2 observations within each grid box.

column_averaging_kernel: XGHG averaging kernel (dimensionless); a vertical profile (1.0E20 = no data). The normalized column-averaging kernel represents the sensitivity of the retrieved XGHG to the true mole fraction depending on pressure (height). All values represent layer averages within the corresponding pressure levels. Values near one are ideal and indicate that the influence of the a priori is minimal. Profiles are ordered from the surface to the top of atmosphere.

vmr_profile_ghg_apriori = {vmr_profile_co2_apriori or vmr_profile_ch4_apriori}: A priori dry-air mole fraction profile of atmospheric CO_2 or CH_4, respectively, expressed as a dimensionless fraction between 0.0 and 1.0 (1.0E20 = no data). All values represent layer averages within the corresponding pressure levels. Profiles are ordered from the surface to the top of atmosphere. The a priori profile is needed to apply the column averaging kernel.

1.5.4. Examples of known climate applications and best practices

The L3 OBS4MIPs XCO_2 and XCH_4 products have been primarily generated for comparison with climate models, see, for example Lauer et al., 2017, and Gier et al., 2020, but have also been used for other applications such as computations of annual mean atmospheric growth rates (e.g., Buchwitz et al., 2018; Reuter et al., 2020).

The L3 XCO_2 and XCH_4 v4.6 OBS4MIPS format data products described in this document (in combination with satellite XCO_2 and XCH_4 retrievals from the CAMS project https://atmosphere.copernicus.eu (last access: 5-Apr-2023), extending the OBS4MIPS data in time) have been used for the Copernicus Press Release issued in January 2023: "Copernicus: 2022 was a year of climate extremes, with record high temperatures and rising concentrations of greenhouse gases" https://climate.copernicus.eu/copernicus-2022-was-year-climate-extremes-record-high-temperatures-and-rising-concentrations (last access: 5-Apr-2023).

1.5.5. Known Issues and Limitations

Until 04/2009, the Obs4MIPs XCO2 dataset was based solely on a SCIAMACHY dataset. This dataset is land-only and of lower quality than the later datasets, which has a direct impact on the Obs4MIPs product. As only one dataset was used during this period, the standard error could not be determined using the ensemble, but only from the validation study.

Until 04/2009, the Obs4MIPs XCH4 dataset was based solely on a SCIAMACHY dataset. Due to technical issues affecting key methane-sensitive detector pixels of the SCIAMACHY instrument, the dataset is land-only from 11/2005 onwards and significantly inferior in quality compared to later datasets. This directly impacts the Obs4MIPs product. As only one dataset was used during this period, the standard error could not be determined using the ensemble, but only from the validation study.

In 01/2015, GOSAT had to switch to the secondary pointing mechanism due to degradation of the primary system. This affected all GOSAT L2 XCO2 and XCH4 L2 products used by EMMA, resulting in a data gap in the Obs4MIPs XCO2 and XCH4 products for this month.

2. Data access information

The data products and corresponding documentation are / will be made available via the Copernicus Climate Data Store (CDS): https://cds.climate.copernicus.eu/#!/home

Direct link to CO_2 products: https://cds.climate.copernicus.eu/datasets/satellite-carbon-dioxide?tab=overview, DOI: 10.24381/cds.f74805c8

Direct link to CH_4 products: https://cds.climate.copernicus.eu/datasets/satellite-methane?tab=overview, DOI: 10.24381/cds.b25419f8

To download the data products, users have to select:

- Processing level: L3
- Variable: Column-average dry-air mole fraction
- Sensor and algorithm: MERGED and OBS4MIPS
- Version: 4.6

Users should first consult the user forum to find out if their question has already been answered. If not, users can use the ECMWF Support Portal to issue their request.

Technical questions, such as problems with data access, will be answered by ECMWF. Specific questions related to the data products will be answered by GHG retrieval experts. It will be aimed to respond as soon as possible (at least 85% if all questions will be answered within 15 working days).

Acknowledgements

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We are also very grateful to the GOSAT/GOSAT-2 teams in Japan comprising the Japan Aerospace Exploration Agency (JAXA), the National Institute for Environmental Studies (NIES), and the Ministry of the Environment (MOE) for providing access to the GOSAT and GOSAT-2 Level 1 and Level 2 data products.

We also acknowledge the availability of OCO-2 Level 1 and Level 2 (XCO2) data products from NASA, which have been used for the generation of the XCO2_OBS4MIPS product. This product also includes OCO-2 XCO2 retrieved at Univ. Bremen with the FOCAL algorithm. The FOCAL activities would not have been possible without funding from University of Bremen, from the EU H2020 projects CHE (grant agreement ID: 776186) and VERIFY (Grant agreement ID: 776810), from ESA via project GHG-CCI+ and from EUMETSAT project FOCAL-CO2M.

The TCCON data were obtained from the TCCON Data Archive hosted by CaltechDATA at https://tccondata.org

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