C3S Greenhouse Gas (GHG: MTCO2 v10.1 & MTCH4 v10.2): Product User Guide and Specification (PUGS)

ECV - Atmospheric Physics

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History of modifications

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Product Version	Issue	Date	Description of modification	Chapters / Sections
MTCO2 v10.1, MTCH4 v10.2	1	19-November-2024	New document	All
MTCO2 v10.1, MTCH4 v10.2	2	14-May-2025	Updated following revision of independent reviewers	All
MTCO2 v10.1, MTCH4 v10.2	3	28-August-2025	Minor adjustments after independent review and finalisation for publication	All

List of datasets covered by this document

› Click here to expand the list of datasets covered by this document

Deliverable ID	Product title	Product type (CDR, ICDR)	Version number	Delivery date
WP1-DDP-GHG-v1	MTCO2_OBS4MIPS	CDR	10.1	31-Oct-2024
WP1-DDP-GHG-v1	MTCH4_OBS4MIPS	CDR	10.2	31-Oct-2024

Acronyms

› Click here to expand the list of acronyms

Acronym	Definition
AMSU	Advanced Microwave Sounding Unit

ATBD	Algorithm Theoretical Basis Document
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)
ECMWF	European Centre for Medium Range Weather Forecasting
ECV	Essential Climate Variable
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCDR	Fundamental Climate Data Record
GHG	GreenHouse Gas
IASI	Infrared Atmospheric Sounding Interferometer
L1	Level 1
L2	Level 2
L3	Level 3
L4	Level 4
LMD	Laboratoire de Météorologie Dynamique
MT	Mid-tropospheric
NA	Not applicable
NetCDF	Network Common Data Format
NLIS	LMD/CNRS *neuronal* network mid/upper tropospheric CO2 and CH4 retrieval algorithm
NOAA	National Oceanic and Atmospheric Administration
Obs4MIPs	Observations for Climate Model Intercomparisons
ppb	Parts per billion
ppm	Parts per million
PQAD	Product Quality Assurance Document
PQAR	Product Quality Assessment Report
PR	(light path) PRoxy retrieval method
REQ	Requirement
TANSO-FTS-2	Fourier Transform Spectrometer on GOSAT-2
TIR	Thermal Infra Red
TR	Target Requirements
TRD	Target Requirements Document
URD	User Requirements Document

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).

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 C3S data products, MTCO2_OBS4MIPS and MTCH4_OBS4MIPS, for the two main anthropogenic greenhouse gases (GHG) carbon dioxide (CO_2) and methane (CH_4), respectively. These products are mid-tropospheric-averaged air mixing ratios (mole fractions) of CO_2 and CH_4 products (noted as MT-CO_2 and MT-CH_4) derived from observations made by the simultaneous observations of IASI (Infrared Atmospheric Sounding Interferometer) and AMSU-A (Advanced Microwave Sounding Unit A) instruments onboard the European Metop-A (July 2007-August 2021), Metop-B (February 2013-December 2021) and Metop-C (since May 2019) platforms.

IASI is a high resolution Fourier Transform Spectrometer based on a Michelson Interferometer coupled to an integrated imaging system that measures infrared radiation emitted from the Earth (https://iasi.cnes.fr/en/IASI/index.htm). Also flying onboard Metop satellites is the AMSU-A instrument, which is a 15-channel microwave radiometer, which measures scene radiances in 15 discrete frequency channels spanning 23-90 GHz. AMSU-A is used to provide temperature profile information about the observed situation.

The combined use of both Metop-A and -B satellites, which followed the same orbit but with nearly half an orbit out of phase, yielded a complete coverage of the Earth in one day until the end of August 2021, when Metop-A was decommissioned. With the launch of Metop-C in 2018, and declared operational in May 2019, these time series will cover a period of about 20 years at the end of Metop-C lifetime allowing the study of trends and rates of change of CO_2 and CH_4 atmospheric mixing ratios in the mid-troposphere.

The MTCO2_OBS4MIPS and MTCH4_OBS4MIPS products are merged multi-sensor MT-CO_2 and MT-CH_4 Level 3 (L3) products with 1^ox1^o spatial resolution daily, generated from individual satellite sensor Level 2 (L2) MT-CO_2 and MT-CH_4 products from Metop-A, -B and -C available between July 2007 and December 2023 (updated every 6 months). Previous versions of this dataset included only L2 products.

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

1. Product Description

In this section an overview of the MTCO2_OBS4MIPS v10.1 and MTCH4_OBS4MIPS v10.2 data products- specified in terms of variable, associated characteristics, processing level(s) and instrument(s) - is given.

Each of these products presented here are retrieved from simultaneous observations of the IASI and AMSU instruments flying together onboard the three successive Metop-A, -B and -C satellites by using a non-linear inference scheme (NLIS) using Multi-Layer Perceptrons (see ATBD MTGHG, 2024 for more details) . IASI hyperspectral observations in the thermal infrared at 7.7 µm (resp. 15 µm), which are sensitive to both temperature and gas concentrations of CH_4 (resp. CO_2), are used in conjunction with microwave observations from the AMSU-A instruments, only sensitive to temperature, to decorrelate both signals (Crevoisier et al., 2009a, 2009b, 2013). Retrievals are thus performed at the AMSU field-of-view resolution which is 40 km at nadir, for a swath of 2200 km, allowing global coverage twice a day at 9:30 am/pm local time.

Figure 1 shows the periods for which each of the three successive Metop satellite provided data to generate the MT-CO_2 and MT-CH_4 products..

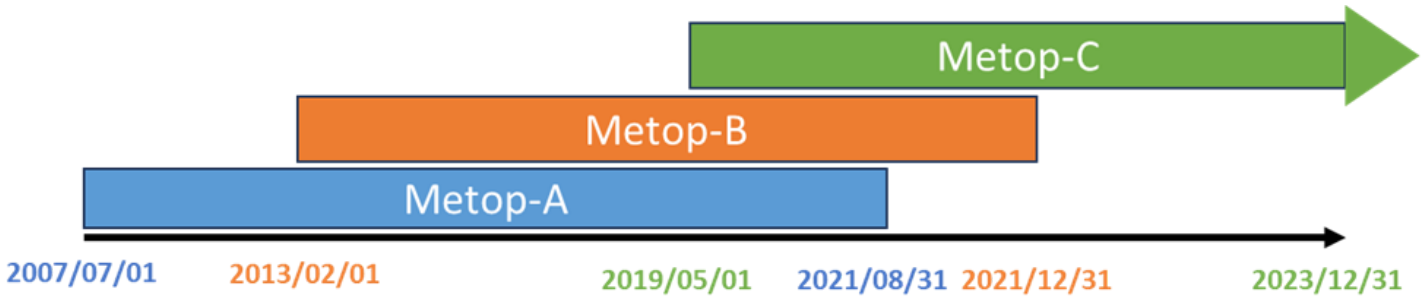

Figure 1: This diagram illustrates the availability of L2 MT-CO_2 and MT-CH_4 products for the three Metop-A, -B and -C platforms between July 2007 and December 2023

The retrieved CO_2 and CH_4 integrated columns are weighted to the tropical mid-troposphere with peak sensitivity at about 230 hPa (~11 km), half the peak sensitivity at 100 and 500 hPa (~6 and 16 km), and no sensitivity to the surface. These mid-tropospheric column-averaged air mixing ratios (mole fractions) of CO_2 and CH_4 are respectively denoted as MT-CO_2 (in parts per million, ppm) and MT-CH_4 (in parts per billion, ppb). Retrievals are performed over land and sea, by night and day (9:30 am/pm local time) for clear-sky only (no clouds, no aerosols). The CO_2 retrievals are limited to the tropical air masses (between about 30°S:30°N). The CH_4 retrievals should not be used outside the 60°S:60°N latitudinal bands.

The Level 3 data products are in Obs4MIPs format and described in detail in Section 1.1 for MT-CO_2 and in Section 1.2 for MT-CH_4. Obs4MIPs (Observations for Model Intercomparisons Project) https://pcmdi.github.io/obs4MIPs/ (last access: 16-03-2025) is an activity to make observational products more accessible especially for climate model intercomparisons.

The MT-CO_2 and MT-CH_4 Obs4MIPs products are gridded data products in NetCDF format with a spatial resolution of 1^ox1^o (i.e., using an equirectangular (Cartesian) latitude/longitude grid) and daily time resolution (see ATBD MTGHG, 2024). The MT-CO_2 and MT-CH_4 Obs4MIPs products are updated every 6 months.

Table 1 provides an overview of the L3 MT-CO_2 and MT-CH_4 data Obs4MIPs products

Table 1: Overview MT-CO_2 and MT-CH_4 Obs4MIPs data products.

Product ID	Level	Sensor(s)	Comments
MTCO2_OBS4MIPS	3	Merged: Metop-A Metop-B Metop-C	Temporal resolution: daily Spatial resolution: 1^ox1^o Latitude range: Tropics (about 30°S:30°N)
MTCH4_OBS4MIPS	3	Merged: Metop-A Metop-B Metop-C	Temporal resolution: daily Spatial resolution: 1^ox1^o Latitude range: Tropics and mid-latitudes (about 60°S:60°N)

The L2 data used as input to generate the MTCO2_OBS4MIPs and MTCH4_OBS4MIPs products are illustrated in Section 1.1 and Section 1.2, respectively.

1.1. Obs4MIPs MT-CO_2 description

The main quantity / data field of this product is the mid-tropospheric column-average air mole fraction of atmospheric carbon dioxide (CO_2), denoted as MT-CO_2.

- L3 MT-CO_2 Obs4MIPs products are computed from L2 version 10.1 MT-CO_2 and MT-CH_4 products from IASI and AMSU-A observations onboard the three Metop platforms (see Figure 1 for MT-CO_2 product availability by platform);
- L2 MT-CO_2 products were produced from IASI L1c and AMSU-A L1b radiance products provided by EUMETSAT through the EUMETCast system;
- L2 MT-CO_2 products are retrieved using the Non Linear Inference Scheme (NLIS) algorithm from CNRS-LMD: version 10.1 for MT-CO_2;
- No bias correction is applied to the L2 MT-CO_2;

For more detailed information on the input data and the processing algorithm see ATBD MTGHG, 2024.

1.2. Obs4MIPs MT-CH_4 description

The main quantity / data field of this product is the mid-tropospheric column-average air mole fraction of atmospheric methane (CH_4), denoted as MT-CH_4.

- L3 MT-CH_4 Obs4MIPs products are computed from L2 version 10.2 MT-CH_4 products from IASI and AMSU-A observations onboard the three Metop platforms (see Figure 1 for MT-CH_4 product availability by platform);
- L2 MT-CH_4 products were produced from IASI L1c and AMSU-A L1b radiance products provided by EUMETSAT through the EUMETCast system;
- L2 MT-CH_4 products are retrieved using the Non Linear Inference Scheme (NLIS) algorithm from CNRS-LMD: version 10.2 for MT-CH_4;
- No bias correction is applied to the MT-CH_4

For more detailed information on the input data and the processing algorithms, see ATBD MTGHG, 2024.

1.3. Overview of Product Target Requirements

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

The achieved data quality of the data products including comparison with the Target Requirements (TR) is described in Section 5 of document Product Quality Assessment Report (MTGHG PQAR, 2024) and reported in Table 2.

Table 2: Compliance with User Requirements. MT-CO_2 and MT-CH_4 Obs4MIPs random ("precision"), systematic error and stability requirements (from TRD GAD GHG, 2024). Abbreviations: G=Goal (green), B=Breakthrough (yellow), T=Threshold requirement (red). §) 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	Comments
		G	B	T		
CO_2	**Random error (precision) (1000^2 km^2 monthly) (ppm)**	< 0.3	**< 1.0**	< 1.3	0.97	This value is based on the comparison between partial column and point measurement.
	Accuracy: Relative systematic error (ppm)	< 0.2 (absolute)	< 0.3 (relative§))	**< 0.5 (relative#))**	1.42	This value is based on the comparison between partial column and point measurement. This value reaches 0.52 ppm between 20°S and 20°N.
	Stability: Linear bias trend (ppm/year)	**< 0.2 (absolute)**	< 0.3 (relative§))	< 0.5 (relative#))	0.005	This value is based on the comparison between partial column and point measurement.
CH_4	**Random error (precision) (1000^2 km^2 monthly) (ppb)**	**< 3**	< 5	**< 11**	17.5	This value is based on the comparison with the AirCores.
	Accuracy: Relative systematic error (ppb)	< 1 (absolute)	**< 5 (relative§))**	< 10 (relative#))	3.80	This value is based on the comparison between partial column and point measurement.
	Stability: Linear bias trend (ppb/year)	< 1 (absolute)	< 2 (relative§))	< 3 (relative#))	NC	Time series of available aircraft/AirCore obs are long enough to compute this parameter.

1.4. Summary data quality for Level 3 MT-CO_2 and MT-CH_4 products

The validation of Level 3 product MTCO2_OBS4MIPS can be summarized as follows:

- The overall monthly mean uncertainty is 1.25 ppm and the mean bias is 0.6 ppm. This value is based on the comparison between partial column (MT-CO_2) and point measurement (Aircraft measurements).
- Relative systematic error, i.e., the spatio-temporal error, is 1.42 ppm (1-sigma) between 30°S:30°N and 0.52 ppm (1-sigma) between 20°S and 20°N. These values are based on the comparison between partial column (MT-CO_2) and point measurement (Aircraft measurements). The computed linear drift of 0.005±0.04 ppm/year (1-sigma) is small and not significant.
- Overall, this product has therefore reasonable accuracy and high stability.

The validation of Level 3 product MTCH4_OBS4MIPS can be summarized as follows:

- The overall monthly mean uncertainty is 17.3 ppb and the mean bias is -1.81 ppb. Relative systematic error, i.e., the spatio-temporal error, is 3.80 ppb (1-sigma).
- Overall, this product has therefore reasonable accuracy.
- The linear drift could not be computed (for more details, see MTGHG PQAR, 2024).

1.5. Example visualization of key variables

Figure 2 shows the monthly averaged maps of L3 MT-CO_2 (a) and L3 MT-CH_4 (b) for August 2020. L3 MT-CO_2 products are limited to tropical airmasses, typically between around 30°S:30°N (Figure 2(a)).

For L3 MT-CH_4 products (Figure 2(b)), the high values of MT-CH_4 are seen over the tropics and northern mid-latitudes. MT-CH_4 values decrease in southern mid-latitudes. There is a high concentration of MT-CH_4 over Asia during the monsoon; the CH_4 emitted by rice paddies, combined with strong convections, rapidly transports CH_4 into the mid-troposphere where it can be observed by IASI infrared sounders.

Figure 3 shows the monthly evolution displayed as a function of latitude of L3 MT-CO_2 and MT-CH_4 retrieved from IASI. Figure 4 shows the seasonal maps of L3 MT-CO_2 Obs4MIPs. The same information but on MT-CH_4 may be found in Figure 5. Figure 4 and 5 clearly show the specific seasonal pattern of methane in the free troposphere. Also, the large and regular increase of both CH_4 and CO_2 in the mid-troposphere is well seen over the 16 years. The figures highlight that the increase impacts the entire globe and seasons homogeneously.

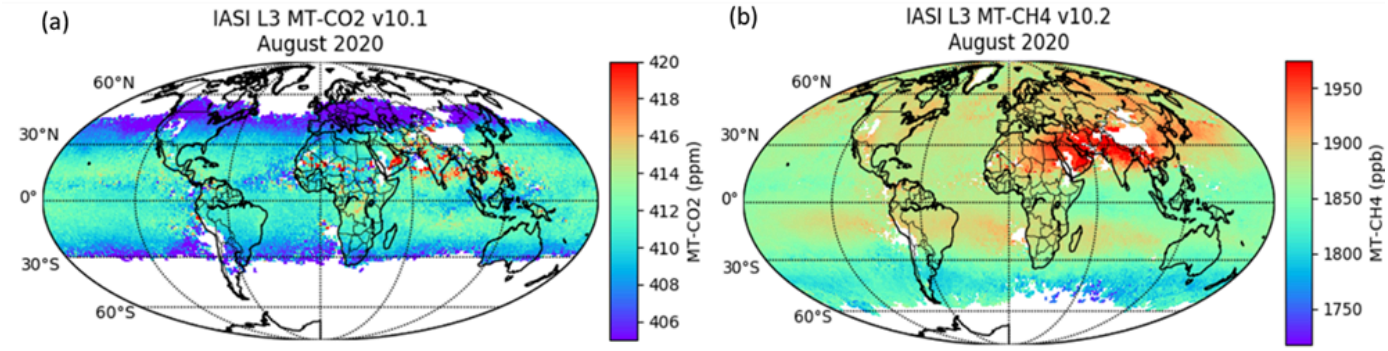

Figure 2: Examples of maps of MTCO2_OBS4MIPS (a) and MTCH4_OBS4MIPS (b) for August 2020

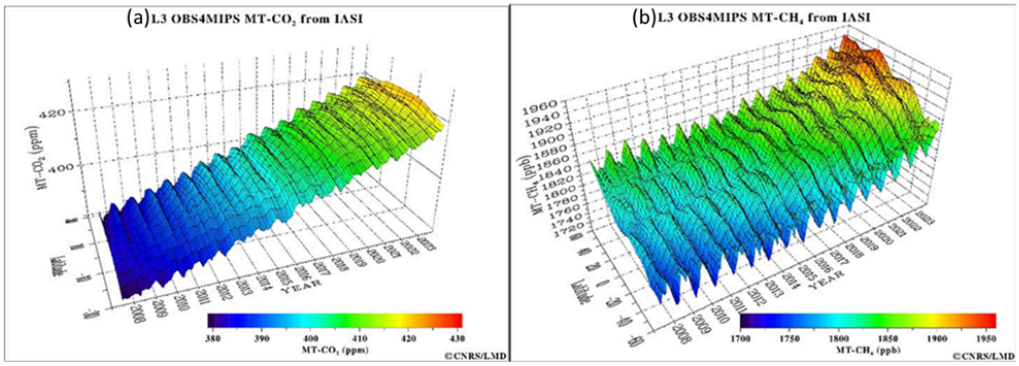

Figure 3: Monthly evolution displayed as a function of latitude of CO_2 (a) and CH_4 (b) mid-tropospheric column averaged mole fraction from L3 MT-CO_2/MT-CH_4 Obs4MIPs.

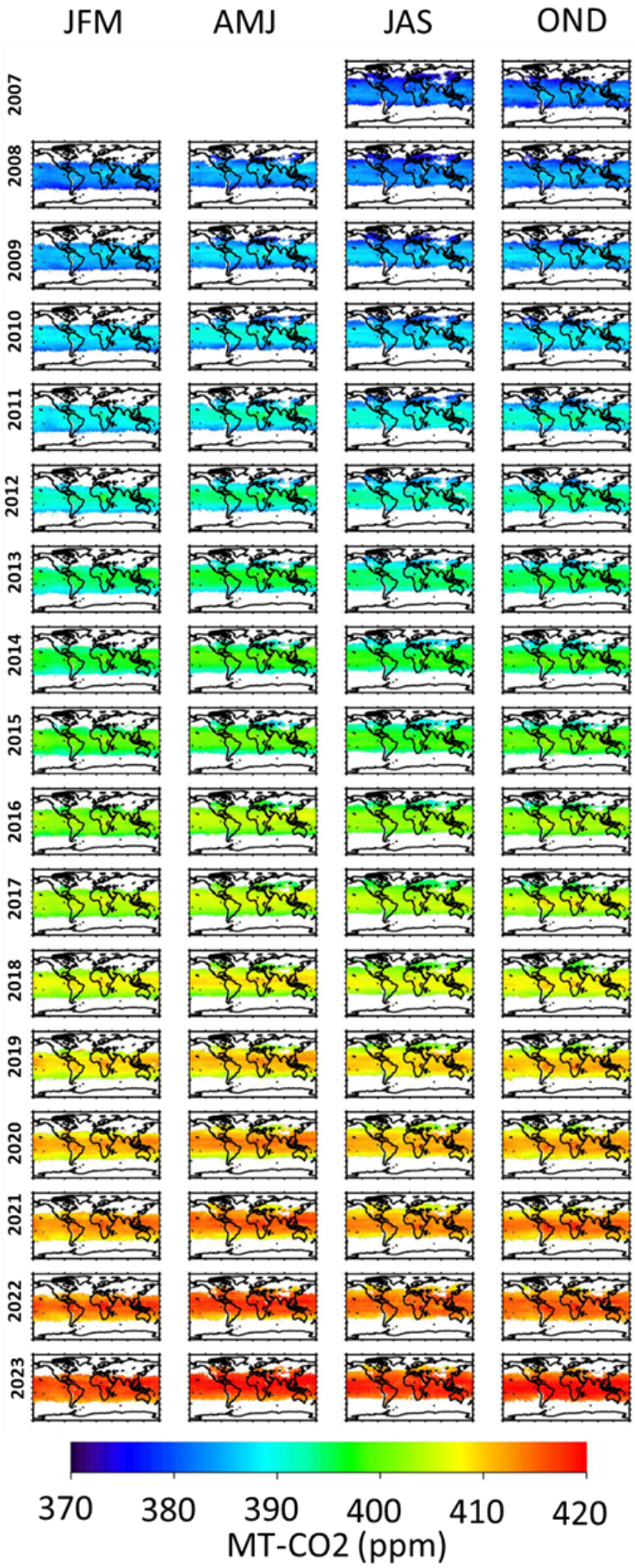

Figure 4: Seasonal maps of MT-CO_2 Obs4MIPs (v10.1) for January-February-March (JFM, 1st column), April-May-June (AMJ, 2nd column), July-August-September (JAS, 3rd column) and October-November-December (OND, 4th column).

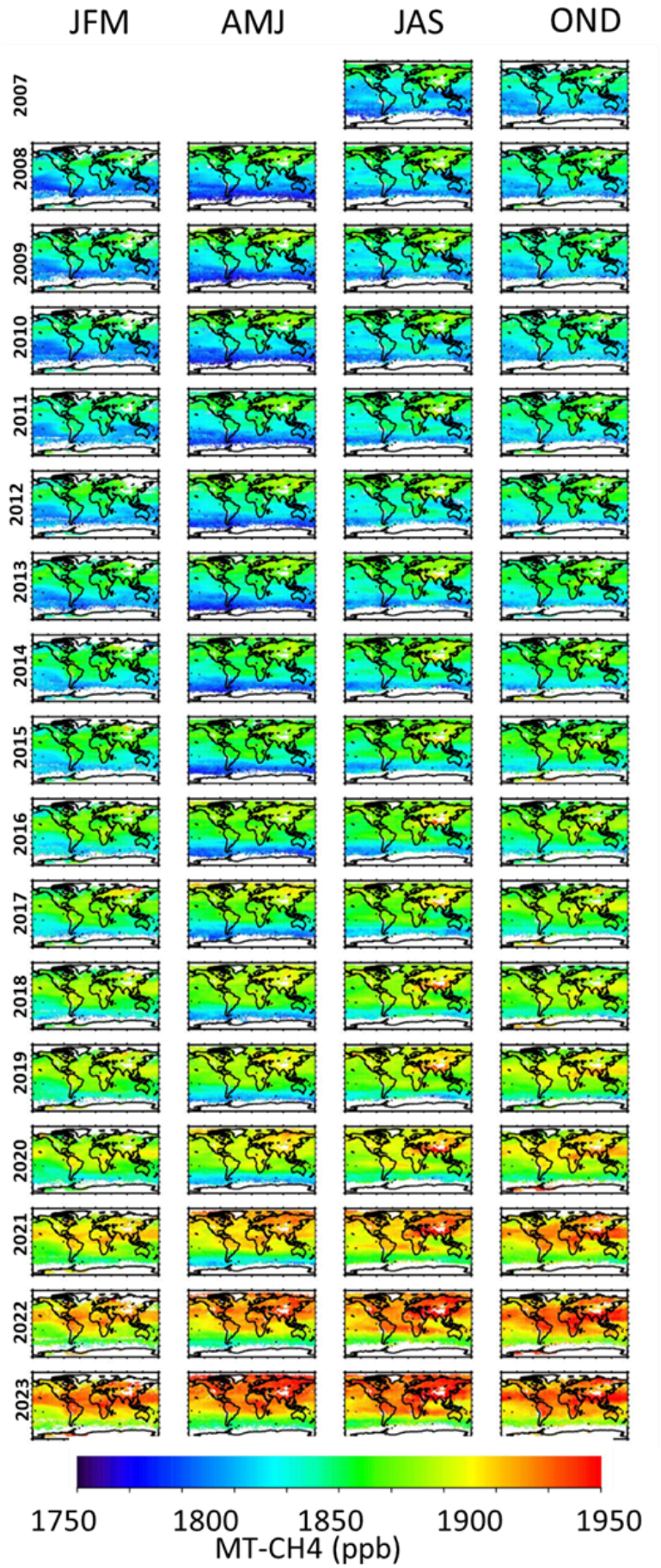

Figure 5: Seasonal maps of L3 MT-CH_4 Obs4MIPs (v10.2) for January-February-March (JFM, 1st column), April-May-June (AMJ, 2nd column), July-August-September (JAS, 3rd column) and October-November-December (OND, 4th column).

1.6. Data usage information

The daily NetCDF (version netcdf=4.8.1, hdf5=1.10.7, Conventions = CF-1.7 ODS-2.1) files contain the level 3 mid-tropospheric column averaged mole fractions of

CH_4 (ppb) and CO_2 (ppm), which are stored as the *mtch4* and *mtco2* variables. Averaging kernels are provided on pressure layers (pressure-weight), as opposed to levels. Averaging kernels provide the CO_2/CH_4 vertical sensitivities of MT-CO_2/CH_4 Obs4MIPs retrievals. They are used for the validation and the comparisons of the MT-CO_2/CH_4 Obs4MIPs with independent source of validation by applying these vertical sensitivities to CO_2/CH_4 profiles measured at the ground to obtain mid-tropospheric columns of CO_2/CH_4 like Obs4MIPs.

1.6.1. Data format and file naming

The MTCO2_OBS4MIPS and MTCH4_OBS4MIPS products are presented in the form of daily NetCDF files with the name convention:

- mtco2_day_C3S-MTCO2-v10.1_BE_gn_YYYYMMDD.nc for MTCO2_OBS4MIPS;
- mtch4_day_C3S-MTCH4-v10.2_BE_gn_YYYYMMDD.nc for MTCH4_OBS4MIPS;
- YYYYMMDD defines the date of the product.

For example, the product named *mtco2_day_C3S-MTCO2-v10.1_BE_gn_20080403.nc* refers to the L3 MTCO2_OBS4MIPS product version 10.1 for the 3rd April 2008.

1.6.2. 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.

1.6.3. File contents

Table 3 and Table 4 list the main characteristics of the MTCO2_OBS4MIPS and MTCH4_OBS4MIPS products, respectively. See ATBD MTGHG, 2024, for an overview of how these products have been generated and for additional details.

Table 3: Main characteristics of the MTCO2_OBS4MIPS v10.1 product.

CF variable name, units	Long name: carbon dioxide mid-tropospheric column carbon dioxide Standard name: mole_fraction_of_carbon_dioxide_in_air 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	1° equal angle
Temporal resolution	daily from July 2007 – December 2023
Coverage	Only for tropical air masses: between about 30°N and 30°S

Table 4: Main characteristics of the MTCH4_OBS4MIPS v10.2 product.

CF variable name, units	Long name: methane dioxide mid-tropospheric column carbon dioxide Standard name: mole_fraction_of_methane_in_air 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	1° equal angle
Temporal resolution	daily from July 2007 – December 2023
Coverage	Only for tropical and mid-latitude air masses

Table 5 lists the variables available in the NetCDF MTCO2_OBS4MIPS and MTCH4_OBS4MIPS products files.

Table 5: Variables available in the NetCDF MTCO2_OBS4MIPS and MTCH4_OBS4MIPS products files. 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	Double	t	Days since 1990-01-01	Time center
time_bnds	Double	t,2	Days since 1990-01-01	Time boundaries
lat	Double	y	Degrees north	Latitude center
lat_bnds	Double	y,2	Degrees north	Latitude boundaries
lon	Double	x	Degrees east	Longitude center
lon_bnds	Double	x,2	Degrees east	Longitude boundaries
pre	Float	z	air pressure	Pressure center
pre_bnds	Float	z,2	air pressure	Pressure boundaries

mt*ghg*	Float	x,y,t	1	Retrieved mid-tropopsheric column of atmospheric CO_2 or CH_4
mt*ghg*_nobs	Integer	x,y,t	1	Number of individual L2 observations
mt*ghg*_std	Float	x,y,t	1	Standard deviation
column averaging kernel	Float	x,y,z,t	1	Column-averaging kernel
**ghg* stands *co2* for MTCO2_OBS4MIPS products and *ch4* for MTCH4_OBS4MIPS products				

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 -90.0º to +90.0º).

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

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

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

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

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

mt*ghg* = {mtco2 or mtch4}: Main parameter: Retrieved mid-tropopsheric column of atmospheric CO_2 or CH_4, respectively. Typical values are << 1.0 (typically close to 0.0004 for MT CO_2 and close to 0.0000018 for MT CH_4) and 1.0E20 = no data.

mt*ghg*_nobs = {mtco2_nobs or mtch4_nobs}: Number of individual MT-GHG L2 observations per grid box used to compute the reported Level 3 XGHG daily average value (0 = no data).

mt*ghg*_std = {mtco2_std or mtch4_std}: Standard deviation of the L2 observations within each grid box.

column_averaging_kernel: MT-GHG averaging kernel (dimensionless); a vertical profile (1.0E20 = no data). The normalized column-averaging kernel represents the sensitivity of the retrieved mid-tropospheric GHG to the true mole fraction depending on pressure (height). All values represent layer averages within the corresponding pressure levels.

1.6.4. Examples of known climate applications and best practices

The Level 3 MT-CO_2 and MT-CH_4 Obs4MIPs products have been primarily generated for comparison with climate models but have also been used for other applications such as computations of annual mean atmospheric growth rates.

Level 3 data are new and thus never used before. Level 2 MT-CO_2 and MT-CH_4 products have been used for flux inversions (Cressot et al., 2014), assimilation within C-IFS (Massart et al., 2014, Agustí-Panareda et al. 2023) or study of methane in the Arctic.

1.6.5. Known Issues and Limitations

For MT-CO_2 Obs4MIPs products:

- The retrievals are limited to Tropical air masses (between about 30°N and 30°S);
- The uncertainties are not provided;

For MT-CH_4 Obs4MIPs products:

- The retrievals are limited to Tropical and Mid-latitude air masses;
- The MT-CH_4 Obs4MIPs retrievals should not be used outside the 60°S:60°N latitudinal bands.
- The uncertainties are not provided;
- The stability of MT-CH_4 Obs4MIPs product could not be calculated from the validation using aircraft measurements.

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

Data can be downloaded from the website and used under the License to Use Copernicus Products (included on the download pages).

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: Level 3
- Variable: Column-average air mole fraction
- Sensor and algorithm: IASI and Obs4MIPs

Version: 10.1 (MT-CO_2) and 10.2 (MT-CH_4)

User support is provided by ECMWF via the ECMWF Support Portal. Questions may also addressed through the user forum.

For specific technical aspects concerning the MT-CO_2 and MT-CH_4 products, users can contact nicolas.meilhac@lmd.ipsl.fr (9am-5pm weekdays).

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