ECMWF COPERNICUS REPORT

Copernicus Climate Change Service

Product User Guide and Specification (PUGS) – ANNEX E for IASI CO_2 and CH_4 (v9.1) and AIRS CO_2 mid-tropospheric products

C3S2_312a_Lot2_DLR – Atmosphere

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History of modifications

Version	Date	Description of modification	Chapters / Sections
1.3	20-October-2017	New document for data set CDR1 (until 2016)	All
2.0	4-October-2018	Update for CDR2 (until 2017)	All
3.0	12-August-2019	Update for CDR3 (until 2018) with additional information on Metop-C	All, esp. Sects. 1.1 and 1.2
3.1	03-November-2019	Update after review by Assimila: Correction of typos and broken links. Improved typesetting of equations.	All
4.0	18-August-2020	Update for CRD4 (until 2019) with new version of the retrieval code	All
5.0	18-February-2021	Update for CRD5 (until 2020)	All
6.0	4-August-2022	Update for CRD6 (until 2021)	All
6.1	6-December-2022	Update after review (use of new template, several improvements at various places)	All
6.3	18-April-2023	Update after 2nd review. Several improvements at various places.	All

List of datasets covered by this document

Deliverable ID	Product title	Product type (CDR, ICDR)	Version number	Delivery date
WP2-FDDP-GHG-v1	CO2_IASA_NLIS, CH4_IASA_NLIS, CO2_IASB_NLIS, CH4_IASB_NLIS	CDR 6	9.1	31-Aug-2022

Related documents

Reference ID	Document
D1	**Main PUGS:** Buchwitz, M., et al., Product User Guide and Specification (PUGS) – Main document for Greenhouse Gas (GHG: CO2 & CH4) data set CDR 6 (2003-2021), project C3S2_312a_Lot2_DLR – Atmosphere, 6.3, 2023. *(this document is an ANNEX to the Main PUGS)*
D2	**TRD GAD GHG, 2020:** Buchwitz, M., Aben, I., Armante, R., Boesch, H., Crevoisier, C., Hasekamp, O. P., Wu, L.., Reuter, M., Schneising-Weigel, O., Target Requirement and Gap Analysis Document, Copernicus Climate Change Service (C3S) project on satellite-derived Essential Climate Variable (ECV) Greenhouse Gases (CO_2 and CH_4) data products (project C3S_312b_Lot2), Version 2.11, 9-April-2020, pp. 80, 2020.
D3	**Related PQAR:** Crevoisier, C., et al.: Product Quality Assessment Report (PQAR) – ANNEX E for IASI CO_2 and CH_4 (v9.1) and AIRS CO_2 mid-tropospheric products, C3S project C3S2_312a_Lot2_DLR, v6.2, 2023.

Acronyms

Acronym	Definition
AIRS	Atmospheric Infrared Sounder
AMSU	Advanced Microwave Sounding Unit
ATBD	Algorithm Theoretical Basis Document
BESD	Bremen optimal EStimation DOAS
CAR	Climate Assessment Report
C3S	Copernicus Climate Change Service
CCDAS	Carbon Cycle Data Assimilation System
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
D/B	Data base
DOAS	Differential Optical Absorption Spectroscopy
EC	European Commission
ECMWF	European Centre for Medium Range Weather Forecasting
ECV	Essential Climate Variable
EMMA	Ensemble Median Algorithm
ENVISAT	Environmental Satellite (of ESA)
EO	Earth Observation
ESA	European Space Agency
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
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems
GHG	GreenHouse Gas
GOME	Global Ozone Monitoring Experiment
GMES	Global Monitoring for Environment and Security
GOSAT	Greenhouse Gases Observing Satellite
IASI	Infrared Atmospheric Sounding Interferometer
IMAP-DOAS (or IMAP)	Iterative Maximum A posteriori DOAS
IPCC	International Panel in Climate Change

IUP	Institute of Environmental Physics (IUP) of the University of Bremen, Germany
JAXA	Japan Aerospace Exploration Agency
JCGM	Joint Committee for Guides in Metrology
L1	Level 1
L2	Level 2
L3	Level 3
L4	Level 4
LMD	Laboratoire de Météorologie Dynamique
MACC	Monitoring Atmospheric Composition and Climate, EU GMES project
NA	Not applicable
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Format
NDACC	Network for the Detection of Atmospheric Composition Change
NIES	National Institute for Environmental Studies
NIR	Near Infra Red
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
OCO	Orbiting Carbon Observatory
OE	Optimal Estimation
PBL	Planetary Boundary Layer
ppb	Parts per billion
ppm	Parts per million
PR	(light path) PRoxy retrieval method
PVIR	Product Validation and Intercomparison Report
QA	Quality Assurance
QC	Quality Control
REQ	Requirement
RMS	Root-Mean-Square
RTM	Radiative transfer model
SCIAMACHY	SCanning Imaging Absorption spectroMeter for Atmospheric ChartographY
SCIATRAN	SCIAMACHY radiative transfer model
SRON	SRON Netherlands Institute for Space Research
SWIR	Short Wava Infra Red
TANSO	Thermal And Near infrared Sensor for carbon Observation
TANSO-FTS	Fourier Transform Spectrometer on GOSAT
TBC	To be confirmed
TBD	To be defined / to be determined
TCCON	Total Carbon Column Observing Network
TIR	Thermal Infra Red

TR	Target Requirements
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
Y2Y	Year-to-year (bias variability)

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.

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.

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).

Intermediate climate data record (ICDR)

An intermediate climate data record (ICDR) is a TCDR which undergoes regular and consistent updates, 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.

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)

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Scope of document

This document is a Product User Guide and Specification (PUGS) for the Copernicus Climate Change Service (C3S, https://climate.copernicus.eu/) greenhouse gas (GHG) component as covered by project C3S2_312a_Lot2.

Within this project satellite-derived atmospheric carbon dioxide (CO_2) and methane (CH_4) Essential Climate Variable (ECV) data products have been generated and delivered to ECMWF for inclusion into the Copernicus Climate Data Store (CDS) from which users can access these data products and the corresponding documentation.

The satellite-derived GHG data products are:

- Column-averaged dry-air mixing ratios (mole fractions) of CO_2 and CH_4, denoted XCO_2 (in parts per million, ppm) and XCH_4 (in parts per billion, ppb), respectively.
- Mid/upper tropospheric mixing ratios of CO_2 (in ppm) and CH_4 (in ppb).

This document describes the C3S products CO2_IASA_NLIS (v9.1), CH4_IASA_NLIS (v9.1), CO2_IASB_NLIS (v9.1), CH4_IASB_NLIS (v9.1), CO2_AIRS_NLIS (v3.0).

These products are mid-tropospheric CO_2 and CH_4 Level 2 products as retrieved from the IASI sensors on Metop-A and Metop-B and mid-tropospheric CO_2 from AIRS sensor on Aqua using algorithms developed at CNRS-LMD, France.

Executive summary

This document describes the data and metadata delivered to the Copernicus Climate Change Service (C3S) for the Level 2 CO_2 and CH_4 data products retrieved from IASI and AIRS observations at CNRS-LMD. These products are mid-tropospheric-averaged dry-air mixing ratios (mole fractions) of CH_4 and CO_2, retrieved at 9:30 am/pm (local time) from observations made by the IASI and AMSU instruments onboard the European Metop-A (July 2006-August 2021) and Metop-B (since February 2013) platforms. They also include CO_2 mid-tropospheric-averaged dry-air mixing ratios derived from observations made by AIRS and AMSU instruments flying onboard Aqua for the period January 2003-June 2006.

Data are provided as daily netCDF files available at the C3S website. Section 1 describes the products. Section 2 gives their target requirements. Section 3 details data usage information, such as data format, averaging kernels, geolocation information, as well as information on performances and limitations. Finally, Section 4 gives information on data access.

1. Product description

1.1 The IASI instrument onboard the Metop platforms

The Infrared Atmospheric Sounding Interferometer (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). Developed by the Center National d'Etudes Spatiales (CNES) in collaboration with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), IASI was launched in October 2006 onboard the polar orbiting Meteorological Operational Platform (Metop-A), in September 2012 onboard Metop-B and in October 2018 onboard Metop-C. The 3 instruments have been declared operational in July 2007, February 2013 and July 2019, respectively. Metop-A nominal operations were stopped in August 2021 to start a series of 'End-of-Life experiments', that resulted in the decommissioning of the platforms and all onboard instruments in October 2021.

The combined use of both Metop satellites, which are flying on the same orbit but with nearly half an orbit out of phase, yields a complete coverage of the Earth in one day. With the launch of Metop-C in 2018, these time series will cover a period of about 20 years allowing the study of trends and rates of change of emissions.

1.2 CH_4 and CO_2 mid-tropospheric column averaged mole fractions

Four Level 2 products are described in this document:

- CH4_IASA_NLIS: mid-tropospheric column averaged mole fractions of CH_4 retrieved from IASI onboard Metop-A.
- CH4_IASB_NLIS: mid-tropospheric column averaged mole fractions of CH_4 retrieved from IASI onboard Metop-B.
- CO2_IASA_NLIS: mid-tropospheric column averaged mole fractions of CO_2 retrieved from IASI onboard Metop-A.
- CO2_IASB_NLIS: mid-tropospheric column averaged mole fractions of CO_2 retrieved from IASI onboard Metop-B.

Each of these products are retrieved from simultaneous observations of the IASI and AMSU instruments flying together onboard the Metop satellites using a non-linear inference scheme using Multi-Layer Perceptrons. 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 form the AMSU 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 40km at nadir, for a swath of 2200 km, allowing global coverage twice a day at 9:30 am/pm local time.

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. 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 region (30N:30S).

Through comparisons with regular aircraft (*Machida et al., 2008)* or balloon *(Membrive et al., 2017*) measurements as well as observations made at the surface, it has been shown that, once the radiometric characterization of the instruments is performed, IASI and AMSU capture well the trend and interannual variation of CH_4, with an excellent agreement with the rate of increase measured at the surface, giving confidence in the ability of IASI to follow its evolution over the 20 years of the Metop program.

Figure 1 shows the daily coverage provided by the use of both Metop-A and Metop-B in terms of mid-tropopsheric CH_4. Figure 2 shows the seasonal maps of mid-tropospheric CH_4 retrieved from Metop-A and -B. The same information but on CO_2 may be found in Figure 3. Figures 2 and 3 clearly show the specific seasonal pattern of methane in the free troposphere, which is the same whatever the year is. Also, the large and regular increase of both CH_4 and CO_2 in the mid-troposphere is well seen over the 15 years. The figures highlight that the increase impacts the entire globe and seasons homogeneously.

Finally, Figures 4 and 5 show the monthly evolution displayed as a function of latitude of mid-tropospheric CO_2 and CH_4 retrieved from Metop-A and Metop-B. These figures summarize the keay features of mid-tropospheric CO_2 and CH_4 : a strong latitudinal gradient, with highest values in the northern hemisphere; a notable seasonality, of opposite signs in the norther and southern hemispheres; a continuous increase over the 15 years of IASI observations.

Figure 1: An example of daily maps of CH_4 mid-tropospheric column averaged mole fraction retrieved from Metop-A, from Metop-B and from both platforms for September, 15th, 2013.

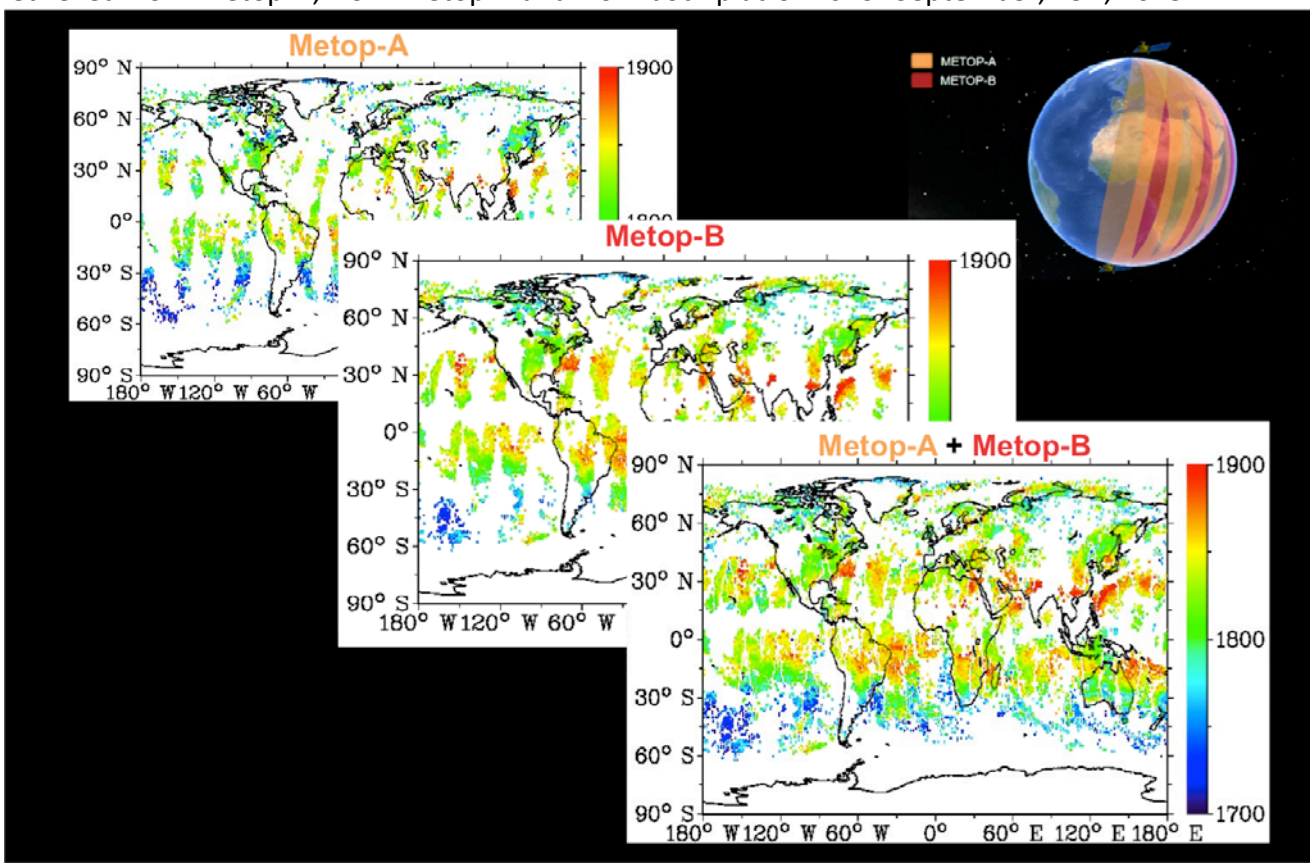


Figure 2: Seasonal maps of mid-tropospheric CH_4 (v9.1) retrieved from Metop-A only (JAS 2007-OND 2012), from Metop-A and Metop-B (JFM 2013-JJA 2021) and from Metop-B only (OND 2021).

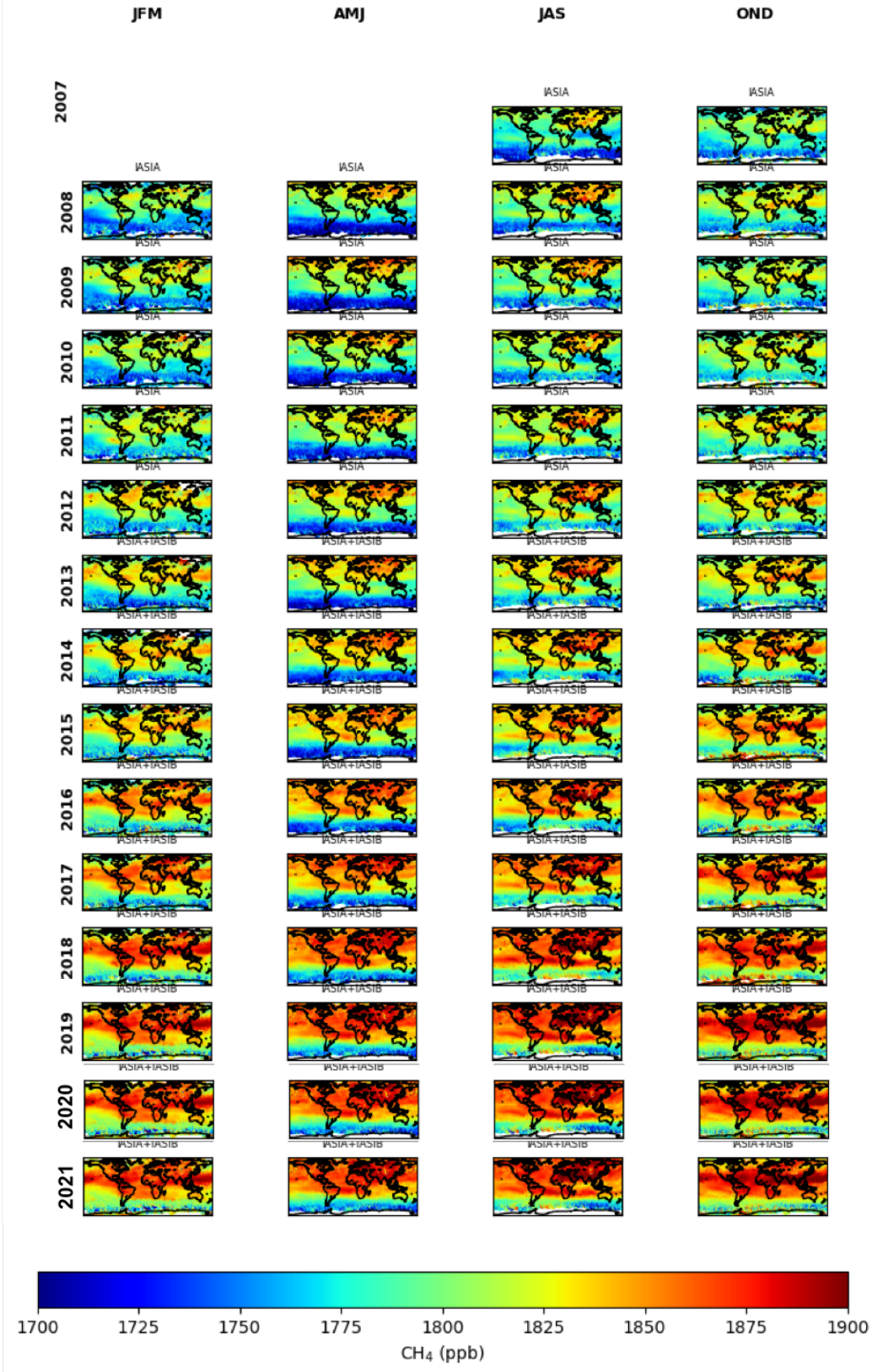


Figure 3: Same as Fig. 2 but mid-tropospheric CO_2 (v9.1).

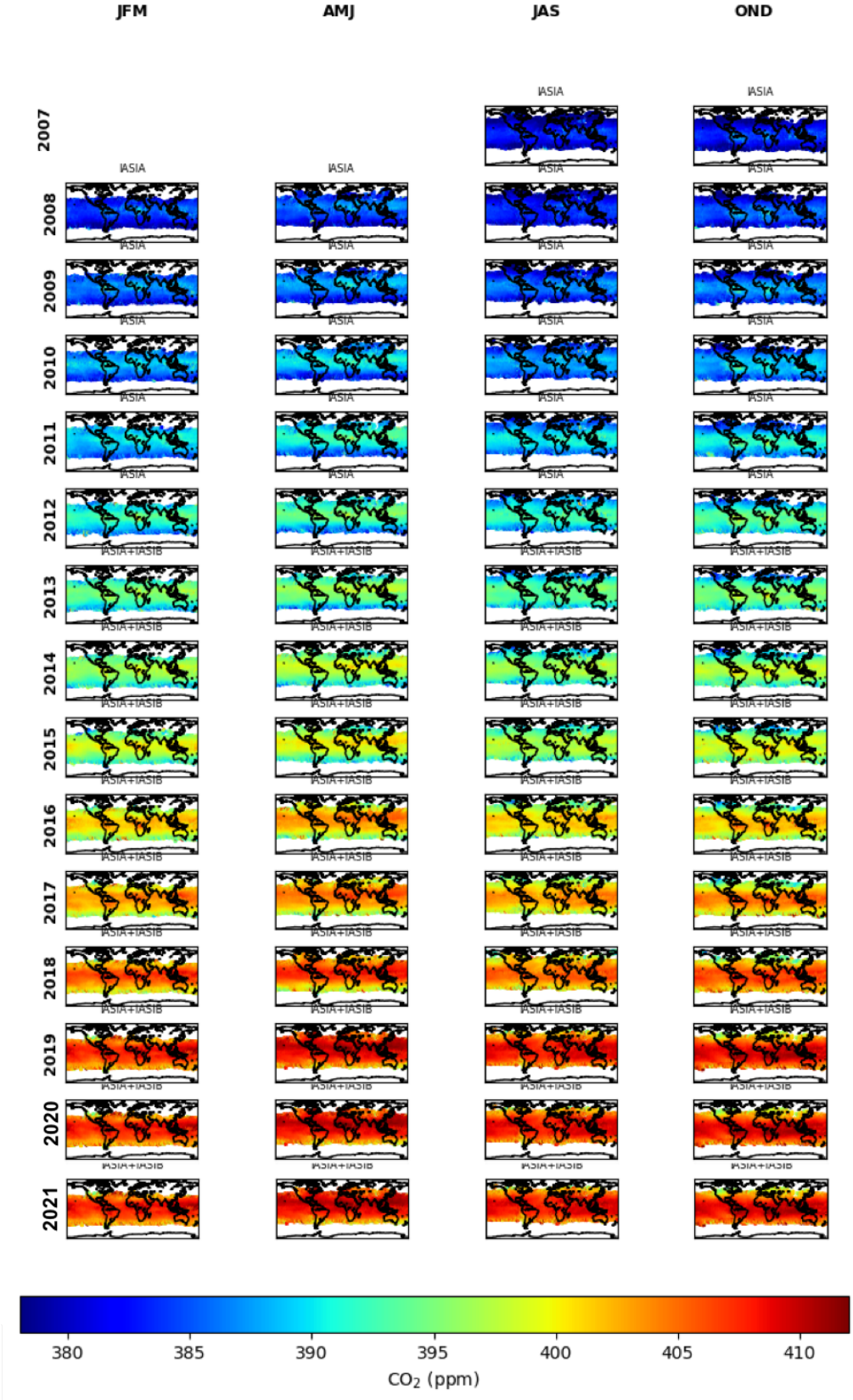


Figure 4. Monthly evolution displayed as a function of latitude of CO_2 mid-tropospheric column averaged mole fraction retrieved from Metop-A and Metop-B combined (version 9.1).

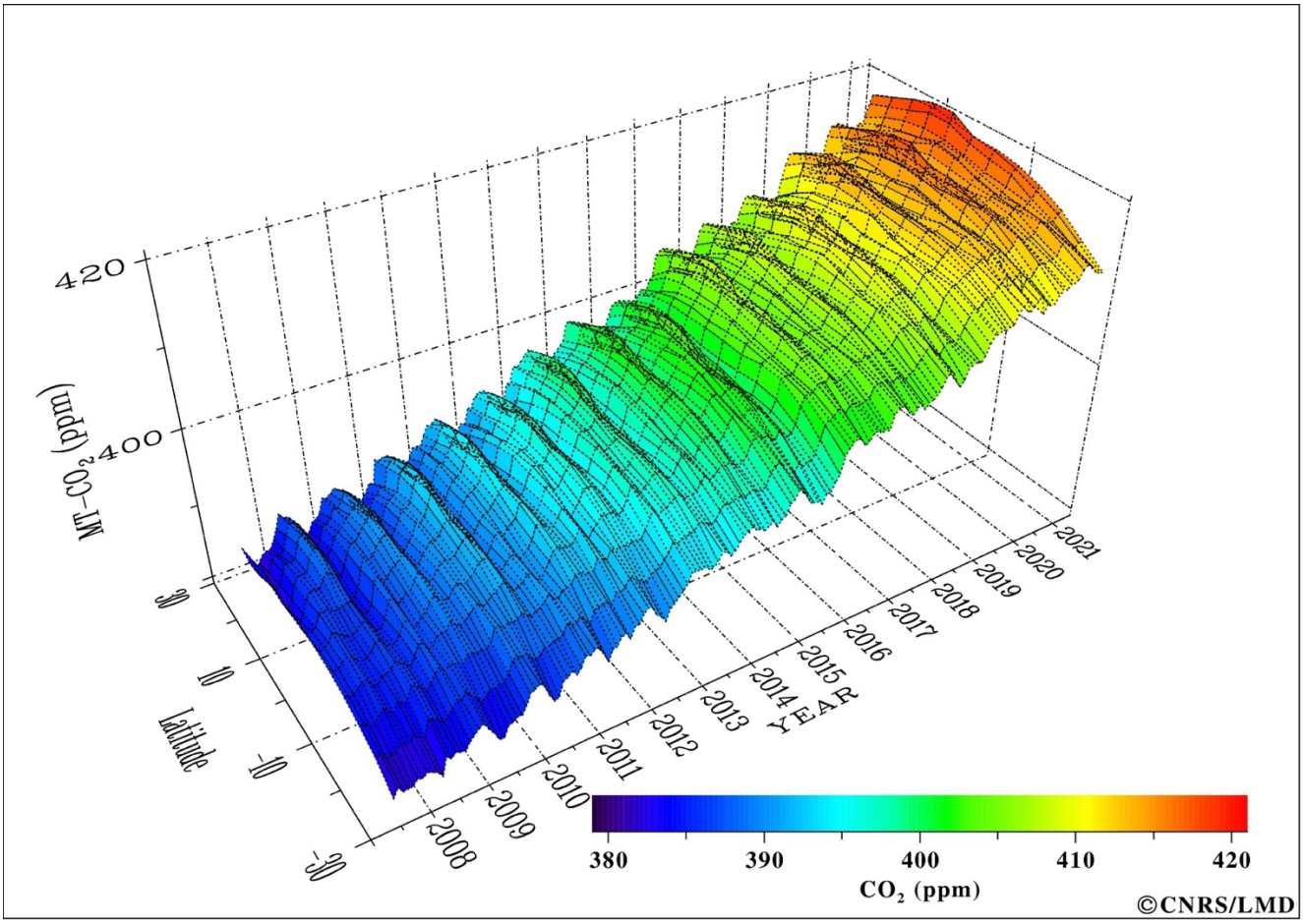
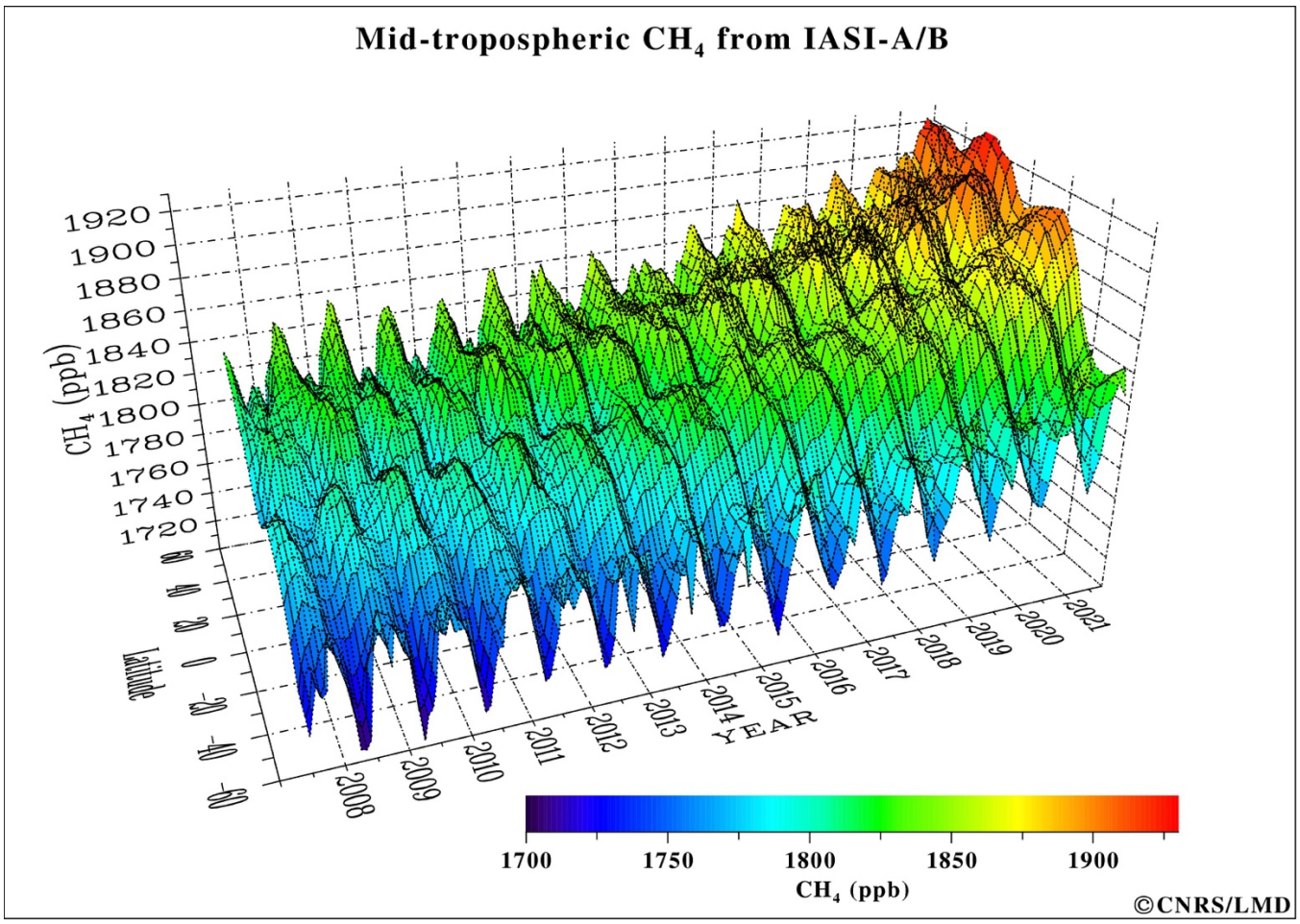


Figure 5. Monthly evolution displayed as a function of latitude of CH_4 mid-tropospheric column averaged mole fraction retrieved from Metop-A and Metop-B combined (version 9.1).



1.3 AIRS CO_2 mid-tropospheric column averaged mole fractions

Level 2 mid-tropospheric column averaged mole fractions of CO_2 are also retrieved from simultaneous observations of the AIRS and AMSU instruments flying together onboard the Aqua satellite since 2002 (*Crevoisier et al., 2003*). This dataset covers the period January 2003-June 2006. Although AIRS is still in operation, the loss of several channels that were used in the retrieval has stopped the generation of retrievals. The dataset generated during the ESA-CCI-GHG initiative has been rewritten as a series of daily netcdf files, following the same structure as the other products. This set of daily products is provided through the C3S service.

2. Target requirements

Quality requirements for Level 2 products generated from IASI and delivered to C3S are discussed in the Target Requirements Document (TRD) (*D2*). Table 1 shows the random and systematic errors stated in the TRD. The evaluation itself of our products is described in the PQAR document (*D3*).

Table 1: Mid/upper tropospheric CO_2 and CH_4 random ("precision") and systematic retrieval error requirements. 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.

Random and systematic error requirements for mid/upper tropospheric CO_2 and CH_4					
Parameter	**Req. type**	**Random error** ("Precision")		**Systematic error**	**Stability**
		Single obs.	1000^2 km^2 monthly		
CO_2	G	< 1 ppm	< 0.3 ppm	< 0.2 ppm (absolute)	As systematic error but per year
	B	< 3 ppm	< 1.0 ppm	< 0.3 ppm (relative §))	As systematic error but per year
	T	< 8 ppm	< 1.3 ppm	< 0.5 ppm (relative #))	As systematic error but per year
CH_4	G	< 9 ppb	< 3 ppb	< 1 ppb (absolute)	< 1 ppb/year (absolute)
	B	< 17 ppb	< 5 ppb	< 5 ppb (relative §))	< 2 ppb/year (relative §))
	T	< 34 ppb	< 11 ppb	< 10 ppb (relative #))	< 3 ppb/year (relative #))

3. Data usage information

3.1 Product content and format

The daily NetCDF (version netcdf=4.7.4, hdf5=1.10.7) files contain the mid-tropospheric column averaged mole fractions of CH_4 (ppb) and CO_2 (ppm), which are stored in the ch4 and co2 variables. The quality flags (0=good) must be applied before use. Averaging kernels are provided on pressure layers (pressure-weight), as opposed to levels. A dimension of *n* refers to the number of retrievals per file. A dimension of *m* refers to the number of levels used in the radiative transfer retrieval process.

Table 2: Variables present in the NetCDF file for the CH4_IASA_NLIS and CH4_IASB_NLIS products.

Name	Type	Dimension	Units	Description
latitude	float	n	degrees_north	Center latitude of the measurement
longitude	float	n	degrees_east	Center longitude of the measurement
time	float	n	seconds since 1970-1-1 0:0:0	Measurement time
solar_zenith_angle	float	n	degrees	Angle between line of sight to the sun and local vertical
sensor_zenith_angle	float	n	degrees	Angle between the line of sight to the sensor and the local vertical
ch4_quality_flag	byte	n		0=good, 1=bad
ch4	float	n	1e-9	Retrieved mid-tropopsheric column of atmospheric methane (CH_4) in ppb
ch4_uncertainty	float	n	1e-9	1-sigma uncertainty of the retrieved Mid-tropospheric-CH_4 in ppb
ch4_averaging_kernel	float	n, m		Normalized column-averaging kernel, which represents the sensitivity of the retrieved mid-tropospheric CH_4 to the atmospheric methane mole fraction depending on pressure (height). All values represent layer averages within the corresponding pressure levels.
pressure_levels	float	n, m	hPa	Pressure levels define the boundaries of the averaging kernel. Surface pressure is represented by the 1st element, i.e., profiles are ordered from surface to top of atmosphere.
pressure_weight	float	n, m	hPa	Layer dependent weights corresponding to pressure levels

Table 3: Variables present in the Netcdf file for the CO2_IASA_NLIS, CO2_IASB_NLIS and CO2_AIRS_NLIS products.

Name	Type	Dimension	Units	Description
latitude	float	n	degrees_north	Center latitude of the measurement
longitude	float	n	degrees_east	Center longitude of the measurement
time	float	n	seconds since 1970-1-1 0:0:0	Measurement time
solar_zenith_angle	float	n	degrees	Angle between line of sight to the sun and local vertical
sensor_zenith_angle	float	n	degrees	Angle between the line of sight to the sensor and the local vertical
co2_quality_flag	byte	n		0=good, 1=bad
co2	float	n	1e-6	Retrieved mid-tropopsheric column of atmospheric methane (CO_2) in ppm
co2_uncertainty	float	n	1e-6	1-sigma uncertainty of the retrieved Mid-tropospheric-CO_2 in ppm
co2_averaging_kernel	float	n, m		Normalized column-averaging kernel, which represents the sensitivity of the retrieved mid-tropospheric CO_2 to the atmospheric methane mole fraction depending on pressure (height). All values represent layer averages within the corresponding pressure levels.
pressure_levels	float	n, m	hPa	Pressure levels define the boundaries of the averaging kernel. Surface pressure is represented by the 1st element, i.e., profiles are ordered from surface to top of atmosphere.
pressure_weight	float	n, m	hPa	Layer dependent weights corresponding to pressure levels

3.2 Tools for reading data

Numerous programming languages exist that can be used for reading and analysing netCDF files. These include both compiled languages such as Java, Fortran and C, and languages that allow interactive analysis and plotting of data. Some examples of the latter are:

Python http://www.python.org/ with add on modules such as:
netCDF4 http://unidata.github.io/netcdf4-python/
NumPy http://www.numpy.org/
xarray http://xarray.pydata.org/en/stable/index.html
matplotlib http://matplotlib.org/
Iris and Cartopy http://scitools.org.uk/iris/
R https://cran.r-project.org with libraries such as:
ncdf4 https://cran.r-project.org/web/packages/ncdf4/index.html
maptools https://cran.r-project.org/web/packages/maptools/index.html
IDL http://www.harrisgeospatial.com/SoftwareTechnology/IDL.aspx
MATLAB https://www.mathworks.com/products/matlab.html

3.3 Recommended data usage

For model comparison or for intercomparison with in-situ or remote-sensing measurements for which vertical profile information is available, use should be made of the provided normalized-column averaging kernels, denoted G. The 40 G_i values are independent of the layer thickness and can be interpolated to any vertical layer distribution. Note that they are normalized so that the sum of the G_i, weighted by layer pressure thickness, is 1. The simulated integrated content of the consider gas, denoted q_{gas}^{other}, is finally given by equation (1)

$$q_{gas}^{other} = \frac{\sum_{i=1}^{M_{lay}} H_i \Delta p_i q_i}{\sum_{i=1}^{M_{lay}} H_i \Delta p_i} \qquad (1)$$

where H_i is the vertical weighting function G_i interpolated on the M_{lay} pressure layers Δp_i used by the other product for which the gas mixing ratio q_i at level P_i is given in ppb.

3.4 Known limitations and issues

• From beginning of 2015, AMSU channel 7 has started degrading and then exceeding specifications. Retrievals performed from IASI/AMSU onboard Metop-A have thus been stopped in August 2015, and more 'bad quality' retrievals have been flagged in the first half of 2015 than the years before. The regeneration of the full dataset without the information given by AMSU7 have been done for V4.1 and beyond.
• For high scan angles (between 10th and 15th angle), the retrievals display a variation with the scan angle that depends on the year, and that can reach quite high values at the edges of the orbits. For these reasons, only retrievals for scan angles lower than the 10th angle are provided.
• A 2 ppm bias was found in CO_2 retrieved from Metop-B with version V4.1. An update of the computation of radiative biases characterizing IASI and AMSU Metop-B channels has been removed when going from version V4.1 to version V4.2.
• Differences in CO_2 partial columns (v9.1) larger than 2 ppm have been observed between Metop-A and Metop-B for latitudes higher than 25°N/S larger.
• Differences in CH_4 partial columns (v9.1) larger than 10 ppb have been observed between Metop-A and Metop-B for latitudes higher than 60°N/S larger.
• A 1ppm bias is found in CO_2 retrieved from Metop-A with version 9.1 from the last months of 2019 and beyond. This is linked to a change in the correction of the detectors non linearity on Metop-A by the end of 2019. This change at instrument level has impacted the radiances themselves in the longwave band of IASI spectrum where the CO_2 absorption bands are located. The full characterization of this change has been carried out. The appropriate corrections will be made and these will be incorporated in the next version (V10.1) to be distributed.

4. 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/cdsapp#!/dataset/satellite-carbon-dioxide?tab=overview

Direct link to CH_4 products:
https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-methane?tab=overview

Tabs / riders lead to the following items:

- Overview
  - Short overview of all products
- Download data
  - Data access information
- Quality assessment
  - The CDS datasets are assessed by the Evaluation and Quality Control (EQC) function of C3S independently of the data supplier and the EQC information are available on this site.
- Documentation
  - Links to the following documents:
    - Algorithm Theoretical Basis Document (ATBD)
    - Product User Guide (PUG)
    - Product Quality Assurance Document (PQAD)
    - Product Quality Assessment Report (PQAR)
    - System Quality Assurance Document (SQAD)
    - Target Requirements and Gap Analysis (TRDGAD)
  - Note that pdf versions of all documents (including previous versions) are (also) available from here: https://www.iup.uni-bremen.de/carbon_ghg/cg_data.html#C3S_GHG
- View
  - Visualization of selected data products in terms of global maps

References

Buchwitz et al., 2015: Buchwitz, M., Reuter, M., Schneising, O., Boesch, H., Guerlet, S., Dils, B., Aben, I., Armante, R., Bergamaschi, P., Blumenstock, T., Bovensmann, H., Brunner, D., Buchmann, B., Burrows, J.P., Butz, A., Chédin, A., Chevallier, F., Crevoisier, C.D., Deutscher, N.M., Frankenberg, C., Hase, F., Hasekamp, O.P., Heymann, J., Kaminski, T., Laeng, A., Lichtenberg, G., De Mazière, M., Noël, S., Notholt, J., Orphal, J., Popp, C., Parker, R., Scholze, M., Sussmann, R., Stiller, G.P., Warneke, T., Zehner, C., Bril, A., Crisp, D., Griffith, D.W.T., Kuze, A., O'Dell, C., Oshchepkov, S., Sherlock, V., Suto, H., Wennberg, P., Wunch, D., Yokota, T., Yoshida, Y., The Greenhouse Gas Climate Change Initiative (GHG-CCI): comparison and quality assessment of near-surface-sensitive satellite-derived CO2 and CH4 global data sets. Remote Sens. Environ. 162:344–362, http://dx.doi.org/10.1016/j.rse.2013.04.024, 2015.

Crevoisier et al., 2003: Crevoisier, C., Chedin, A. and Scott, N.A., AIRS channel selection for CO_2 and other trace-gas retrievals 129, 2719–2740. doi:10.1256/qj.02.180, 2003.

Crevoisier et al., 2004: Crevoisier, C., S. Heilliette, A. Chédin, S. Serrar, R. Armante, and N. A. Scott, Midtropospheric CO_2 concentration retrieval from AIRS observations in the tropics, Geophys. Res. Lett., 31, L17106, doi:10.1029/2004GL020141, 2004.

Crevoisier et al., 2009a: Crevoisier, C., Chédin, A., Matsueda, H., et al., First year of upper tropospheric integrated content of CO_2 from IASI hyperspectral infrared observations, *Atmos. Chem. Phys.*, 9, 4797-4810, 2009.

Crevoisier et al. 2009b: Crevoisier, C., Nobileau, D., Fiore, A., Armante, R., Chédin, A., and Scott, N. A.: Tropospheric methane in the tropics – first year from IASI hyperspectral infrared observations, Atmos. Chem. Phys., 9, 6337–6350, doi:10.5194/acp-9-6337-2009, 2009b.

Crevoisier et al., 2013: Crevoisier, C., Nobileau, D., Armante, R., et al., The 2007–2011 evolution of tropical methane in the mid-troposphere as seen from space by MetOp-A/IASI, *Atmos. Chem. Phys.*, 13, 4279-4289, 2013.

ESA-CCI-GHG-URDv3.0: Chevallier, F., et al., User Requirements Document (URD), ESA Climate Change Initiative (CCI) GHG-CCI project, Version 3.0, 17 Feb 2020, pp. 42, link: https://www.iup.uni-bremen.de/carbon_ghg/docs/GHG-CCIplus/URD/URDv3.0_GHG-CCIp_Final.pdf, 2020.

GCOS-154: Global Climate Observing System (GCOS): SYSTEMATIC OBSERVATION REQUIREMENTS FOR SATELLITE-BASED DATA PRODUCTS FOR CLIMATE - 2011 Update - Supplemental details to the satellite-based component of the “Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)”, December 2011, prepared by World Meteorological Organization (WMO), Intergovernmental Oceanographic Commission, United Nations Environment Programme (UNEP), International Council for Science, Doc.: GCOS 154, link: http://cci.esa.int/sites/default/files/gcos-154.pdf, 2011.

GCOS-200: The Global Observing System for Climate: Implementation Needs, World Meteorological Organization (WMO), GCOS-200 (GOOS-214), pp. 325, link: http://unfccc.int/files/science/workstreams/systematic_observation/application/pdf/gcos_ip_10oct2016.pdf, 2016.

Jacquinet-Husson et al., 2011: Jacquinet-Husson, N., Crepeau, L., Armante, R., et al. (2011). The 2009 edition of the GEISA spectroscopic database. J. Quant. Spectrosc. Radiat. Transf. 112, 2395–2445. doi:10.1016/j.jqsrt.2011.06.004.

Scott and Chédin, 1981: Scott, N.A. and Chédin, A., A Fast Line-by-Line Method for Atmospheric Absorption Computations: The Automatized Atmospheric Absorption Atlas. J. Appl. Meteorol. 20, 802–812. doi:10.1175/1520-0450(1981)020<0802:AFLBLM>2.0.CO;2, 1981.

TRD GHG, 2017: Buchwitz, M., Aben, I., Anand, J., Armante, R., Boesch, H., Crevoisier, C., Detmers, R. G., Hasekamp, O. P., Reuter, M., Schneising-Weigel, O., Target Requirement Document, Copernicus Climate Change Service (C3S) project on satellite-derived Essential Climate Variable (ECV) Greenhouse Gases (CO_2 and CH_4) data products (project C3S_312a_Lot6), Version 1, 28-March-2017, pp. 52, 2017.

TRD GAD GHG, 2020: Buchwitz, M., Aben, I., Armante, R., Boesch, H., Crevoisier, C., Hasekamp, O. P., Wu, L.., Reuter, M., Schneising-Weigel, O., Target Requirement and Gap Analysis Document, Copernicus Climate Change Service (C3S) project on satellite-derived Essential Climate Variable (ECV) Greenhouse Gases (CO_2 and CH_4) data products (project C3S_312b_Lot2), Version 2.11, 9-April-2020, pp. 80, 2020.

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