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Product Quality Assessment Report (PQAR) – ANNEX E for IASI CO₂ and CH₄ and AIRS CO₂ mid-tropospheric products

C3S_312a_Lot6_IUP-UB – Greenhouse Gases

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History of modifications

Version	Date	Description of modification	Chapters / Sections
1.0	26-September-2017	New document	All
1.0b	11-October-2017	Page header logo replaced	Page header
1.1	20-October-2017	KPI replaced by TR	All



Related documents

Reference ID	Document
	Main PQAR:
D1	Buchwitz, M., et al., Product Quality Assessment Report (PQAR) – Main document, C3S project C3S_312a_Lot6_IUP-UB – Greenhouse Gases, v1.1, 2017. (this document is an ANNEX to the Main PQAR)



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 <i>neuronal</i> network mid/upper tropospheric CO2 and CH4 retrieval algorithm					
NOAA	National Oceanic and Atmospheric Administration					
Obs4MIPs	Observations for Climate Model Intercomparisons					
000	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

Table 1 lists some general definitions relevant for this document.

Table 1: General definitions.

Item	Definition
XCO ₂	Column-averaged dry-air mixing ratios (mole fractions) of CO ₂
XCH₄	Column-averaged dry-air mixing ratios (mole fractions) of CH ₄
L1	Level 1 satellite data product: geolocated radiance (spectra)
L2	Level 2 satellite-derived data product: Here: CO ₂ and CH ₄ information for
	each ground-pixel
L3	Level 3 satellite-derived data product: Here: Gridded CO_2 and CH_4
	information, e.g., 5 deg times 5 deg, monthly
L4	Level 4 satellite-derived data product: Here: Surface fluxes (emission and/or
	uptake) of CO ₂ and CH ₄



Scope of document

This document is a Product Quality Assessment Report (PQAR) for the Copernicus Climate Change Service (C3S, <u>https://climate.copernicus.eu/</u>) component as covered by project C3S_312a_Lot6 led by University of Bremen, Germany.

Within project C3S_312a_Lot6 satellite-derived atmospheric carbon dioxide (CO₂) and methane (CH₄) Essential Climate Variable (ECV) data products will be 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 C3S_312a_Lot 6 satellite-derived data products are:

- Column-average dry-air mixing ratios (mole fractions) of CO₂ and CH₄, denoted XCO₂ (in parts per million, ppm) and XCH₄ (in parts per billion, ppb), respectively.
- Mid/upper tropospheric mixing ratios of CO₂ (in ppm) and CH₄ (in ppb).

This document describes the validation / quality assessment of the C3S products CO2_IASA_NLIS, CH4_IASA_NLIS, CO2_IASB_NLIS, CH4_IASB_NLIS, CO2_AIRS_NLIS.

These products are mid-tropospheric CO₂ and CH₄ Level 2 products as retrieved from the IASI sensors on Metop-A and Metop-B and mid-tropospheric CO₂ from AIRS using algorithms developed at CNRS-LMD, France.

Executive summary

This document describes the performance for the Level 2 CO₂ and CH₄ data products retrieved from IASI observations at CNRS-LMD and delivered to the Copernicus Climate Change Service (C3S). These products are mid-tropospheric-averaged dry-air mixing ratios (mole fractions) of CH₄ and CO₂, retrieved at 9:30 am/pm (local time) from observations made by the IASI and AMSU instruments onboard the European Metop-A (since July 2006) and Metop-B (since February 2013) platforms.

IASI and AIRS observations were spatially and temporally collocated with observations made from aircraft measurements from the CONTRAIL and HIPPO programs, as well as with observations made from balloons using AirCores. When enough in-situ data were available, a number of statistics, including accuracy and stability, have been computed from the difference between in-situ measurements and retrievals from space observation. Overall, the CNRS-LMD products are found to be highly stable and meet the Target Requirement (TR) requirements for accuracy and stability. It has to be noted that, due to too sparse a validation data for CH4, the TR for stability could not be computed. This calls for continuous effort in performing and developing continuous airborne observations of greenhouse gases.



1. Product validation methodology

1.1 CH₄ and CO₂ mid-tropospheric column averaged mole fractions

The validation is performed for five Level 2 products:

- CO2_IASA_NLIS: mid-tropospheric column averaged mole fractions of CO₂ retrieved from IASI onboard Metop-A.
- CO2_IASB_NLIS: mid-tropospheric column averaged mole fractions of CO₂ retrieved from IASI onboard Metop-B.
- CH4_IASA_NLIS: mid-tropospheric column averaged mole fractions of CH₄ retrieved from IASI onboard Metop-A.
- CH4_IASB_NLIS: mid-tropospheric column averaged mole fractions of CH₄ retrieved from IASI onboard Metop-B.
- CO2_AIRS_NLIS: mid-tropospheric column averaged mole fractions of CO₂ retrieved from AIRS onboard Aqua.

The four first products have been 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 with 2 hidden layers. IASI hyperspectral observations in the thermal infrared at 7.7 μ m (resp. 15 μ m), which are sensitive to both temperature and gas concentrations of CH₄ (resp. CO₂) are used in conjunction with microwave observations from the AMSU instruments, only sensitive to temperature, to decorrelate both signals (*Crevoisier et al., 2009a, 2009b, 2013*). The fifth product has been similarly obtained with AIRS and AMSU observations.

Potential radiative systematic biases existing between simulations used in the inference scheme and observations are computed for each channel by averaging, over the instruments full years of operation, the differences between simulations and collocated (in time and space) satellite observations. The simulations are performed using the 4A/OP-2009 forward model (*Scott and Chédin, 1981*; http://www.noveltis.net/4AOP/), which is based on the updated 2011 version of the GEISA spectroscopic database (available at http://ether.ipsl.jussieu.fr/) (*Jacquinet-Husson et al., 2011*), and radiosonde measurements from the Analyzed RadioSoundings Archive database (available at http://ara.lmd.polytechnique.fr). IASI calibrated radiance spectra (level1c) are received through the EUMETCast near real time data distribution service via the French Ether center (http://ether.ipsl.jussieu.fr).

The retrieved CO₂ and CH₄ 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 CO₂ retrievals are limited to the tropical region (30N:30S) because of the greater stability of the temperature atmospheric



profile, which helps decorrelating temperature from gas in the observed radiances, yielding a much better precision compared to the extratropics.

1.2 Validation data and method

Validation against high precision / low systematic errors reference observations is required for the mid/upper troposphere CO_2 and CH_4 data products. Unfortunately, measurements of both gases in the free troposphere and stratosphere are every sparse. Validation thus mostly relies on existing aircraft and airborne measurements.

A promising way consists in using 0-30 km profiles measured by balloon-borne AirCores (*Karion et al., 2010; Membrive et al., 2017*) to which averaging kernels can be apply to derive columns that can then be compared to those derived from space. So far, only a few profiles have been acquired, all in the northern hemisphere. In this validation exercise, use will be made of CH₄ profiles measured at Timmins (Ontario, Canada) and Sodankylä (Finland). Spanning 2014-2016, they will be used to validate both Metop-A and Metop-B retrievals (CH4_IASA_NLIS and CH4_IASB_NLIS).

2. Validation Results

2.1 Products CO2_IASA_NLIS and CO2_IASB_NLIS

2.1.1 Validation

Figure 1 shows comparison of IASI CO₂ mid-tropospheric columns with commercial aircraft measurements made as part of the CONTRAIL project (*Matsueda et al. 2008, Machida et al., 2008, Sawa et al., 2008*) as monthly means in 12 latitudinal bands of 5° each. Figure 2 shows the scatter plot of IASI CO₂ vs. CONTRAIL CO₂ for the whole period. The R correlation coefficient is 0.96, the bias and the standard deviation of the difference between both being 0.57 ± 0.99 ppmv.

To compute the various parameters summarized in the following tables, the time series in each latitudinal bands displayed in Figure 1 has been used separately.



5 Cach. Statistics over July 2007 December 2014.												
Latitudinal	30S:	25S:	20S:	15S:	10S:	5S	EQ:	5N:	10N:	15N:	20N:	25N:
band	25S	20S	15S	10S	5S	:EQ	5N	10N	15N	20N	25N	30N
	1.09	0.92	0.64	0.34	0.11	0.26	0.21	0.08	0.26	0.56	0.96	1.51
	±	±	±	±	±	±	±	±	±	±	±	±
CONTRAIL	1.04	0.79	0.68	0.59	0.78	0.88	0.80	0.69	0.71	1.00	1.17	1.40

Table 1. Mean and standard deviation of CO₂ (ppm): difference between CONTRAIL and IASI over 12 latitudinal bands of 5° each. Statistics over July 2007-December 2014.

Table 1 shows the mean CONTRAIL-IASI CO₂ difference together with the associated standard deviation recorded in each latitudinal band. The mean single measurement is 0.99 ppm, while the mean CONTRAIL-IASI bias over all latitudinal band is 0.57 ppm.

Figure 1: Monthly variation of IASI mid-tropospheric CO₂ V4.0 (full line) and of CONTRAIL CO₂





Figure 2: Scatter plot of IASI mid-tropospheric CO_2 vs. CONTRAIL CO_2 measured at 10 km over the whole period depicted in Fig. 3.1 (July 2007 – December 2014) measured by aircraft at 10 km (dashed line) in 12 latitudinal bands of 5° each.



The relative systematic error is computed as the standard deviation of the CONTRAIL – IASI bias obtained in each latitudinal band. It is computed as two values:

- the "relative spatial bias", which is the standard deviation of the mean per-latitudinal band bias computed over the entire time series. It comes to 0.46 ppm.
- The "relative spatio-temporal bias", which is the standard deviation of the seasonal mean bias in each latitudinal band (i.e. JFM, AMJ, JAS, OND). It comes to 0.49 ppm.

For each latitudinal band, the linear drift was computed as the slope of the linear regression of the mean CONTRAIL –IASI bias against time. Table 2 shows the resulting drift and error. The main drift over the whole bands is: -0.01 ± 0.01 ppm/year.

Latitudinal	306.	255.	205.	155.	105.	59	FO	5 NI ·	10NF	15N·	2011	25 NI+
5° each. Statis	tics over	July 2007	7-Decemb	oer 2014.								
lable 2. iviear	n and star	ndard dev	lation of	CO ₂ (ppr	n): aittere	ence betv	veen COr	NI RAIL ar	ia iasi ov	er 12 lati	tudinai b	ands of

Latitudinal	30S:	25S:	20S:	15S:	10S:	5S	EQ:	5N:	10N:	15N:	20N:	25N:
band	25S	20S	15S	10S	5S	:EQ	5N	10N	15N	20N	25N	30N
Linear drift [ppm/year]	-0.01	0.08	0.06	-0.02	-0.04	-0.09	-0.12	-0.07	-0.03	0.01	0.04	0.01

Finally, the year-to-year stability in each latitudinal band was computed as the difference between the maximum and the minimum values of the monthly differences within each year. This stability was found to be 2.64 ± 0.79 ppm/year.



2.1.2 Validation summary

The validation results are summarized in the table below.

Table 2 - Pr	roduct Quality	Summary	Table for	product CO2_	IASA_NL	IS.
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Product Quality Summary Table for Product: CO2_IASA_NLIS Level: 2, Version: 7.0, Time period covered: 4.2009 – 12.2015									
Parameter [unit]	Achieved performance	Requirement	TR	Comments					
Single measurement precision (1-sigma) in [ppm]	0.99	< 8 (T) < 3 (B) < 1 (G)	-	-					
Mean bias [ppm]	0.57	-	-	No requirement but value close to zero expected for a high quality data product.					
Accuracy: Relative systematic error [ppm]	Spatial – spatiotemporal: 0.46 / 0.49	< 0.5	Probability that accuracy TR is met: 100%	-					
Stability: Drift [ppm/year]	-0.01 ± 0.01 (1-sigma)	< 0.5	Probability that stability TR is met: 100%	-					
Stability: Year-to-year bias variability [ppm/year]	2.64 ± 0.79 (1-sigma)	< 0.5	-	-					

For CO2_IASB_NLIS, it has not been possible to perform such an analysis yet, due to lack of coverage of the aircraft data for the corresponding years. A direct comparison between CO2_IASA_NLIS and CO2_IASB_NLIS has revealed an average bias of 1.98 ± 0.25 ppm between the two products. This bias is currently under study and will be analyzed for the next release.



2.2 Products CH4_IASA_NLIS and CH4_IASB_NLIS

2.2.1 Validation

For CH₄ products, only two quantities have been evaluated so far: single measurement precision, and mean bias with both aircraft and AirCore measurements. Due to limited time series of both aircraft (2 full years of CONTRAIL data for CH₄, only 17 AirCore profiles spanning 2014-2016), it has not yet been possible to evaluate the stability criteria.

2.2.1.1 Validation with aircraft measurements

Retrievals are compared with measurements made in the framework of the CONTRAIL project (*Machida et al., 2007, 2008; Matsueda et al., 2008; Sawa et al., 2008*). All IASI retrievals falling in a 5°x5° grid cell centered on each CONTRAIL measurement are averaged. Figure 3 shows the scatter plot of each pair of CONTRAIL / IASI CH₄. Over the whole dataset (311 pairs), the difference between CONTRAIL and IASI CH₄ is -0.89 ± 16.13 ppb, with a correlation R factor of 0.81.

Figure 3: CONTRAIL CH₄ vs. IASI CH₄ for all CONTRAIL measurements over July 2007-December 2014. The 1x1 line is shown as black. Difference between CONTRAIL and IASI CH₄ is -0.89 ± 16.13 ppb, with a correlation R factor of 0.81.



Figure 4 shows the monthly evolution of CH₄ as measured by CONTRAIL (dashed lines) and retrieved by IASI (full line) for 6 latitudinal bands of 10° each. The monthly evolution observed on both datasets is consistent whatever the latitude is, both in terms of seasonality and amplitude. Table 3 summarizes the statistics (mean and standard deviation) obtained within each 7 latitudinal bands for IASI, CONTRAIL and the difference between both. Both datasets are statistically in agreement. Biases of less than 5 ppb, except for 20S:10S is observed. The standard deviations of IASI and CONTRAIL inside a given latitudinal band are noticeably close to each other, with again the exception of the 20S:10S band for which very few observations are available.

Latitudinal band	30S:20S	205:105	10S:EQ	EQ:10N	10N:20N	20N:30S	30N:40N
CONTRAIL	1773.6 ±	1769.3	1772.7	1785.1	1803.1	1811.1	1810.4
	12.1	± 9.3	± 10.0	± 13.3	± 18.5	± 14.9	± 22.7
IASI	1763.7 ±	1766.3	1764.4	1781.5	1809.1	1809.8	1809.6
	13.3	± 19.8	± 11.0	± 22.5	± 21.0	± 16.1	± 19.8
IASI-	9.9	2.9	8.2	3.6	-5.9	1.31	0.79
CONTRAIL	± 15.7	± 14.0	± 10.5	± 19.8	± 18.0	± 20.8	± 27.3

Table 4. Mean and standard deviation of CH ₄ (ppb): as measured by CONTRAIL aircrafts, as retrieved by IASI, and
difference between the two over 7 latitudinal bands of 10° each. Statistics over July 2007-December 2014.

Figure 4: Comparison between CONTRAIL and IASI CH₄ over July 2007-December 2014. Monthy evolution of CONTRAIL CH₄ (dashed line) and IASI CH₄ (full line) for 6 latitudinal bands of 10° each.



From Table 4, it is straightforward to compute the "relative spatial bias" of the "relative systematic error", which is the standard deviation of the mean per-latitudinal band bias computed over the whole time series. The Accuracy is found to be 5.2 ppb. Due to several gaps in the time series, as well seen in Figure 4, it is not possible to compute the "relative spatio-temporal bias" which is the standard deviation of the seasonal mean bias in each latitudinal band.

2.2.1.2 Validation with AirCore 0-30 km profiles

Here, IASI CH₄ retrievals are compared to several AirCore profiles from measurements made at Timmins (Ontario, Canada) and Sodankylä (Finland) (*Membrive et al., 2017*). All IASI retrievals falling in a 5°x5° grid cell centered on each AirCore profile for the same day are averaged. Figure 5 shows the scatter plot of each pair of AirCore/IASI CH₄. Over the whole dataset (17 pairs for Metop-A and for Metop-B), the difference between AirCore and IASI CH₄ is 2.8 ± 8.5 ppb for Metop-A and 0.4 ± 9.9 ppb for Metop-B.



Figure 5: Comparison between IASI CH₄ (red for Metop-A and blue for Metop-B) and AirCore CH₄.

2.2.1.3 Comparison between CH4_IASA_NLIS (Metop-A) and CH4_IASB_NLIS (Metop-B)

A direct comparison between mid-tropospheric CH₄ fields retrieved from Metop-A and Metop-B yields a global bias close to zero and a standard deviation less than 5 ppbv. Figure 6 shows the seasonal maps (3 month average) of mid-tropospheric CH₄ for the year 2014 retrieved from Metop-A and Metop-B, as well as the difference between the two and the associated standard deviation. The Metop-A and -B derived fields are close to each other. However, a small but negative bias over tropical oceans and a small but positive bias over Africa and to a lesser extent Australia can be observed on the map. These biases appear to be constant throughout the year. Such constant biases might be due to the fact that the systematic radiances for Metop-B used in the retrieval process have been computed over a reduced period, with very few radiosoundings over sea and without taking into account any potential scan dependency. The availability of more years of

observations to compute the radiative biases will help clarifying this point. The consistency of cloud detections between both satellites should also be assessed.

Figure 6: Seasonal maps (3 month average) of mid-tropospheric CH₄ as retrieved from Metop-A (1st column), Metop-B (2nd column), and mean (3rd column) and standard deviation (4th column) of the difference between Metop-A and Metop-B for the year 2014.



2.2.2 Validation summary

The validation results are summarized in the table below for CH4_IASA_NLIS. Please refer to Section 2.2.1.3 for comparison between CH4_IASA_NLIS and CH4_IASB_NLIS.

Table 3: Product Quality Summary Table for products CH4_IASA_NLIS (NC stands for Not computed due to lack of available data).

Product Quality Summary Table for Product: CH4_IASA_NLIS							
Level: 2, Version: 7.0, Time period covered: 4.2009 – 12.2015							
Parameter [unit]	Achieved	Requirement	TR	Comments			
	performance						
Single measurement	11.9	< 34 (T)	-	-			
precision (1-sigma) in [ppb]		< 17 (B)					
		< 9 (G)					
Mean bias [ppb]	-1.3	-	-	No requirement but			
				value close to zero			
				expected for a high			
				quality data product.			
Accuracy: relative	5.2	< 10	Probability that	-			
systematic error [ppb]			accuracy TR is met:				
			100%				
Stability: Linear bias trend	NC	< 3	NC	Time series of			
[ppb/year]				available			
Stability: Year-to-year bias	NC	< 3	-	aircraft/AirCore obs			
variability [ppb/year]				are not long enough			
				to compute these 2			
				parameters			



2.3 Product CO2_AIRS_NLIS

2.3.1 Validation

Use is made of in situ observations made by commercial airliners from April 1993 to March 2007 between Japan and Australia (data available at http://gaw.kishou.go.jp/wdcgg.html). These observations, partly analyzed by *Matsueda et al. (2002)*, are available on a monthly basis. They cover the altitude range 9–13 km. Several gaps have affected the measurements throughout the period, which prevents making robust statistics from them.

The seasonal cycles of CO₂ measured by JAL are plotted in Fig. 7 for the period 2005-2006 (only period with fullcoverage). AIRS retrieved CO₂ cycle is also plotted in Fig. 7. There is a good agreement between both datasets in terms of the phase and amplitude of the seasonal cycle. Overall, the JAL – AIRS CO₂ difference is -0.43 \pm 1.32 ppm.

Beginning of mid-2006, the bias between aircraft and AIRS CO₂ increases (negative sign), up to July 2007 when AIRS channels used to perform the retrievals were lost. This might be due to a non-corrected trend, which has affected either the AMSU observations in late 2006 and 2007, or some of the AIRS channels, which started exceeding radiometric specifications.

Figure 7: CO_2 seasonal cycle in the northern tropics as measured by JAL/CONTRAIL aircrafts (black) and as retrieved from AIRS (orange).





2.3.2 Validation summary

Table 6: Product Quality Summary Table for products CO2_AIRS_NLIS.

Product Quality Summary Table for Product: CO2_AIRS_NLIS							
Level: 2, Version: 7.0, Time period covered: 4.2009 – 12.2015							
Parameter [unit]	Achieved	Requirement	TR	Comments			
	performance						
Single measurement	1.32	< 8 (T)	-	-			
precision (1-sigma) in [ppb]		< 3 (B)					
		< 1 (G)					
Mean bias [ppb]	-0.43	-	-	No requirement but			
				value close to zero			
				expected for a high			
				quality data product.			

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