CO2M Ground-Based Network Reference Product Performance Requirements

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Document Change Record

Version	*Version Date (as on profile)*	*DCR* No. if applicable*	*Description of Changes*
1	25/10/2021		Initial version
1A	16/12/2023		After review by GHG, NO2 and Aerosol level-2, and Cal/Val science teams Requirements for aerosol products added.
2A	31/07/2024		Version after Cal/Val phase 1
2B	07/01/2025		Version for Cal/Val phase 2
2C	01/04/2026		Version for GHG GBP network call

DCR = Document Change Request

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1 INTRODUCTION

1.1 Purpose and Scope

This is the CO2M Greenhouse-Gas (GHG), NO2 and Aerosol Ground-Based Network Reference Product Performance Requirements document. The purpose of this document is to specify the product performance requirements for products derived from ground-based measurements and their networks (in the following called GBP), capable to measure and deliver column-averaged dry-air mole fractions of carbon dioxide (XCO_2) and methane (XCH_4), tropospheric column nitrogen dioxide (NO_2), and Aerosol properties measurements for the purpose of validating, verifying and monitoring the Copernicus CO2M mission user product quality.
Relation to Other Documents

1.2 Applicable Documents

ID	Document Title	Reference and Version
[SRD]	CO2M System Requirements Document [SRD]	EUM/COPER-CO2M/REQ/19/1059478, v2
[CONV]	CO2M Conventions and Terms Document [CO2M-CONV]	EUM/COPER-CO2M/DOC/19/1093368, v1A
STA	Technical report and associated data on footprints of XCO2 measurements and decomposition of column content	EUM/CO/21/4600002562/RL, v1 Available at: CO2M cal/val requirements science support | EUMETSAT
DAT	CO2M Cal-Val Technical report D6.1.4 network performance parameter ranges http://co2m.aeronomie.be	EUM/COPER-CO2M/DOC/24/1421396, v2 Available at: CO2M cal/val requirements science support | EUMETSAT

1.3 Reference Documents

	Document Title	Reference
[ECRC]	An Operational Anthropogenic CO_2 Emissions Monitoring & Verification Support Capacity – Needs and high level requirements for in situ measurements	European Commission Joint Research Centre, EUR 29817 EN. doi: 10.2760/182790
[MRD]	Copernicus CO2 mission requirements document	EOP-SM/3088/YM-ym, v3

1.4 Acronyms

Additional definitions of conventions, terms and abbreviations applicable to the CO2M programme can be found in [CONV]. Abbreviations specific to this document are listed in the following table.

Acronym	*Definition*
AOD	Aerosol Optical Depth
AOI	Area Of Interest
CF	Central Facility
CLIM	CLoud IMager
CO2M	CO2 mission
CO2I	CO2 instrument on the CO2 mission platform
COCCON	Collaborative Carbon Column Observing Network
FOV	Field Of View
FRM	Fiducial Reference Measurement
FT	Fourier Transformation
FTIR	Fourier Transform Infrared
FTS	Fourier-Transform Spectrometer
GBP	Ground-Based reference Products
HKTM	House-Keeping Telemetry
HQ	Headquarters
ICD	Interface Control Document

Acronym	*Definition*
MAP	Multi-Angle Polarimeter
NetCDF	Network Common Data Format
NIR	Near Infra-Red
NO2I	NO2 instrument on the CO2 mission platform
NWC	Nowcasting
NWP	Numerical Weather Prediction
NRT	Near Real Time
PFS	Product Format Specification
QA	Quality Assurance
QC	Quality Control
RINGO	Readiness of ICOS for Necessities of integrated Global Observations
RT	Real time
SNR	Signal to Noise Ratio
SWR	Short-Wave infra-Red
SSO	Sun-Synchronous Orbit
SZA	Solar Zenith Angle
TCCON	Total Carbon Column Observing Network
UTC	Universal Time Coordinated
VIS	VISible

1.5 Conventions and Terminology

For conventions and terminology we refer to the CO2M Conventions and Terms Document [CONV].

1.6 Document Structure

Section Number	Title	Content
1	Introduction	Scope of the document, which also addresses conventions and terminology used in the rest of the document and lists applicable and reference documents.
2	The CO2M System	High level overview of the CO2M mission, space segment and ground segment.
3	CO2M USER Product requirements	Summary of CO2M product relevant CO2M system requirements
4	Ground-based network product requirements for CO2M	Requirements definition for the CO2M ground-based network reference product performance.

1.7 Open issues

Issue #	*Title*	*Content*	*Status*	*Closing version*	*Date*

2 THE CO2M SYSTEM

2.1 Overview of the CO2M mission

The CO2M mission is the space component of the European integrated monitoring and verification support capacity (MVS) dedicated to the monitoring of anthropogenic CO2 emissions. This CO2-MVS is part of the 2021-2027 Copernicus programme component by the European Commission and will be implemented jointly by ESA, EUMETSAT and ECMWF. This European anthropogenic CO2 MVS has the following objectives [ECRC]:

1. The operational provision of atmospheric CO2 measurements obtained from dedicated space-borne sensors, complemented by in-situ networks and ancillary observations;
2. The operational provision of **anthropogenic CO2 emission** maps and anthropogenic emission maps, with high spatial and temporal resolution, and short time updates;
3. The operation of a data-assimilation system, which will integrate atmospheric measurements with bottom-up information into consistent and accurate estimates of anthropogenic CO2 emissions and their trends.
4. The provision of a decision support tool.

The system role for the CO2M mission is a partnership put in place between ESA and EUMETSAT. ESA is responsible for the Space Segment development and its commissioning including LEOP activities, and EUMETSAT is responsible for the provision of the operational ground segment (with contributions from ESA), as well as for the CO2M system operations during the routine phase.

The CO2M Mission Data Processing System (MDPS) and its operational products provided by EUMETSAT and its partners, will contribute to the 1st objective of the integrated observation system.

The CO2M mission products will be used together with other products coming from other components of the MVS (such as ground-based measurements, bottom-up information on CO2 emissions from fossil fuel consumption (e.g. inventories), forecast and analysis model data, etc.) in the MVS operational data assimilation system to estimate the anthropogenic CO2 emissions and their trend. The resulting emission estimations will then support the decision-making process at end-user level.

The full products list of the CO2M missions is as follows:

- User output products (L2) according to [SRD]:
  - Column-averaged dry-air mixing-ratio of CO2: XCO2
  - Column-averaged dry-air mixing ratio of CH4: XCH4
  - NO2 tropospheric column (TTC)
  - Aerosol and cloud information

- solar induced fluorescence (SIF) of vegetation

- Additional calibrated radiometric products (L1) used for the generation of user output products:
  - Top of the atmosphere (TOA) spectral radiance and reflectance at high spectral resolution suitable for the XCO2, XCH4, NO2 and SIF retrievals
  - Multi-viewing and polarized radiance information for aerosol and cloud retrievals
  - Cloud imager radiance information for cloud detection

The space segment of the CO2M consists of one (or several) satellite(s), whose payload instruments perform the optical measurements.

The instruments on board the CO2M satellite(s) are:

- A high resolution visible (VIS), near-infrared (NIR) and shortwave infrared (SWIR) spectrometer called CO2I/NO2I to support the CO2, CH4, NO2 and SIF measurements
- A multi-angle polarimeter called MAP for aerosol and cloud measurements
- A cloud imager called CLIM for cloud detection

The CO2M mission targets the provision of observations globally with on average a weekly effective coverage over land for a single platform at latitudes above 40 degrees, at 4 km² spatial resolution and a precision better than 0.7 ppm in XCO2. Global effective coverage within 3 to 4 days is targeted for a constellation of three platforms.

The mission requirements summarize the following product performances at level-2 (XCO2) [MRD]:

Table 2.1: Characteristics of the geophysical product as required from the space component of the anthropogenic CO_2 monitoring system [MRD].

Parameter	***Level-2 requirement***
XCO_2 precision	*0.7 ppm for vegetation scenario at SZA of 50 degrees*
XCO_2 systematic error	*<0.5 ppm, see also note*
XCO_2 spatial resolution	*4 km², aspect ratio ≤2*
XCO_2 plume image	*Imaging capability of 250 x 250 km² spatial scale*

XCO_2 emission area temporal coverage	*Global coverage and on average once per week effective coverage over land for latitudes above 40 degrees, where the strongest emitting areas are located*
Aerosol and cloud information for accurate XCO_2 retrieval	*High accuracy XCO_2 retrieval requires spatially and temporally collocated* *1) aerosol & cloud information (e.g., vertical profile, optical depth, size distribution and composition) needed to calculate their effect on optical path length in CO_2 spectral bands,* *2) detection of low cloud fractions (5%) of optically thick clouds,* *3) measuring CH_4 spectral bands (allowing proxy retrieval of XCO_2),* *4) measuring solar induced fluorescence for correction in O_2-A band*
NO_2 plume images for locating CO_2 plumes	*Tropospheric NO_2 shall be measured spatially and temporally collocated with XCO_2 at the same spatial resolution and with a NO_2 precision of $1.5 \cdot 10^{15}$ molec/cm^2. This anthropogenic proxy supports the emission estimates by identifying the XCO_2 source, plume direction and local wind speed*

Note 1: applications exploiting the CO_2 plume imaging capability drive the precision requirement.

Note 2: aerosol and (thin) cloud information are expected to come from measurements using a multi-angle polarimeter (MAP), which shall enable good CO_2 observations up to an AOD of 0.5.

Note 3: one satellite may not be enough to deliver the required effective coverage. The overall system requirements will be reached after full-deployment of a constellation of several satellites.

Note 4: XCO_2 systematic error is assumed to be after bias correction.

Note 5: aerosol measurements serve for correction purposes, but will also generate as 'by-product' aerosol height with ~500 m uncertainty and AOD with uncertainty of ~0.05.

Note 6: CH_4 band measurements for proxy retrieval will also generate as 'by-product' XCH_4 products with uncertainty of about ~10 ppb.

The CO2M product requirements for all level-1b, c and 2 products at system level are provided in [SRD]. CO2M product requirements as relevant to the ground-based network product performance are detailed in Section 4.

2.2 Space Segment

2.2.1 The CO2/NO2 spectrometer instrument (CO2I/NO2I)

The CO2I/NO2I instrument is a push-broom imaging spectrometer covering four spectral bands in the visible, near and short-wave infrared region.

The CO2I/NO2I instrument has a FOV of 20.4 degrees with 110 across track pixels with a spatial sampling distance of approximately 1.9 km ALT and 2.1 km ACT.

In order to enable observations of NO_2 plumes, NO2I will cover the visible (VIS) spectral range from 405 to 490 nm. The CO2I covers the near infra-red (NIR) Oxygen A-band region between 747 and 773 nm, and the 1590 to 1675 and 1990 to 2095 nm ranges in the SWIR for the estimation of the observed light path, the detection of CO2, and of Methane. The spectral resolution varies from 0.6 nm in the visible to 0.12 in NIR to 0.3 and 0.35 in the two SWIR bands (see Figure 2.1).

Table 2.2: Spectral bands, resolution, oversampling and SNR

Spectral band	Spectral range	Spectral resolution	Spectral oversampling	Number of spectral pixels	Signal-to-noise ratio (from [MRD]) at reference signal L_{ref}
	[nm]	FWHM of ISRF [nm]	[-]	[-]	[-] @ [photons/s/nm/cm2/sr]
VIS	405-490	0.34	6.5	2048	750 @ 1.35×10^{13}
NIR	747-773	0.11	6.3	2048	330 @ 6.4×10^{12}
SWIR-1	1590-1675	0.30	2.96	1024	400 @ 2.1×10^{12}
SWIR-2	1990-2095	0.36	2.92	1024	400 @ 1.8×10^{12}

The spatial sampling distance is 2.07 by 1.97 km (ACT/ALT).

Figure 2.1 shows four simulated TOA spectra for the four NO2I/CO2I spectral bands for a mid-latitude dark surface (vegetation) scene.

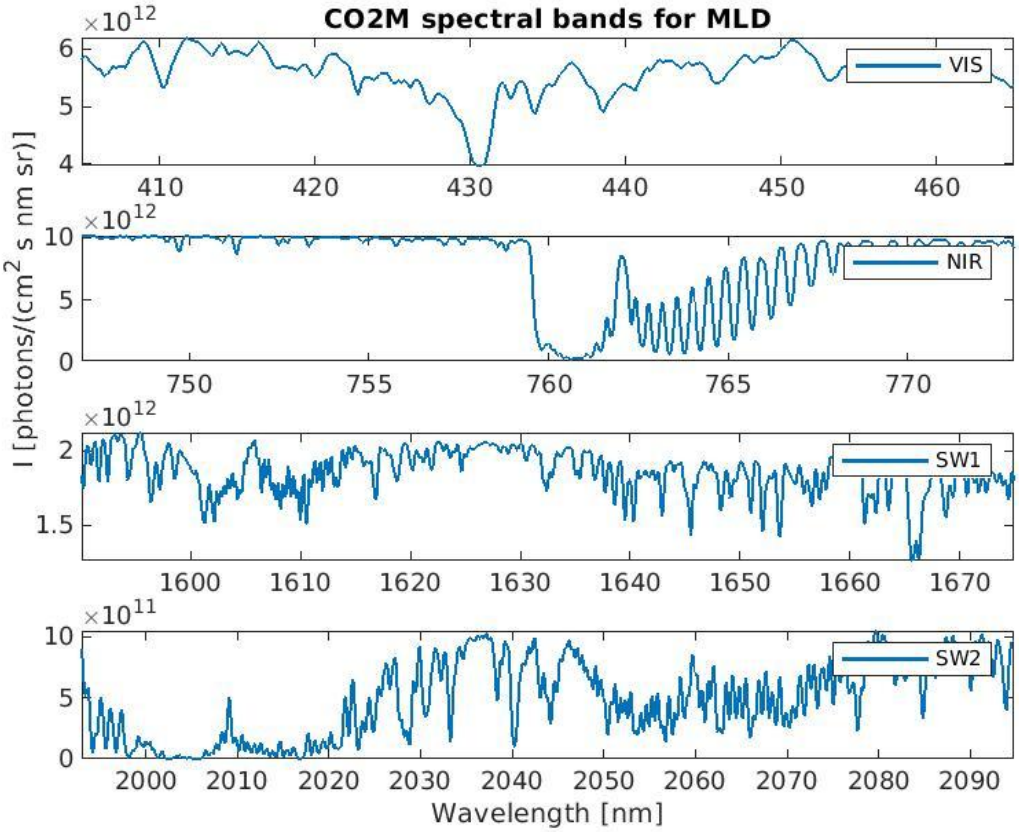

Figure 2.1: ToA simulated radiances for CO2M for all four bands and for a reference target of a mid-latitude vegetation land surface case (Mid-Latitude Dark (MLD)).

2.2.2 The Multi Angle Polarimeter (MAP) on CO2M

The Multi-Angle Polarimeter (CO2M-MAP) instrument is supporting the CO2/CH4 main instrument retrievals from CO2M with the detection of aerosol properties and by correcting the forward calculation of the geometrical light-path due to aerosol scattering in the retrieval.

The CO2M-MAP instrument level-1B product provides multi-angle polarised radiances as input to subsequent co-registration and co-location to the main spectrometer instrument footprint at MAP-L1C.

The CO2M-MAP instrument level-1B multi-angle polarised radiance product will provide more than 45 angles covering at least +/-60 degrees of platform observation viewing angle over a swath of about 280 km at nadir. While the native swath width of the instrument is significantly

larger (370 km; only the part of the swath which covers the swath of the main CO2 spectrometer instrument (271 km), plus some margin, will be processed on-ground.

The MAP level-1B observations are sampled at 1 by 1 km at nadir, with a Spatial Energy Distribution Footprint (SEDF) of about 4 by 4 km. The significant spatial oversampling of the sampled footprint will greatly reduce radiometric errors due to re-sampling. TOA radiances are provided at the native sampling of 1 by 1 km.

Co-registration and resampling of the MAP-L1B stokes-vector radiances to the footprint of the CO2I/NO2I instrument is done using the level-1C processor developed at EUMETSAT for the EPS-SG 3MI instrument. The level-1C product contains multi-angle observations co-registered at surface altitude with respect to the wgs84 ellipsoid using a Digital Elevation Model (DEM) of about 90 meters resolution.

The MAP-L1C product will be input to subsequent processing of level-2 products.

The MAP will measure polarised radiances in 6 spectral channels at 410, 443, 490, 555, 670, and 865 nm with a spectral width of around 20 nm (40nm for the 865 nm channel). In addition, there are non-polarised measurements by an additional channel at 753 nm at a spectral width of 9 nm to allow for cross-calibration between the CLIM and the NIR channel of the CO2I.

The absolute radiometric accuracy including Degree of Linear Polarisation (DoLP) is continuously monitored and potentially re-calibrated by solar and lunar measurements at regular time intervals, which will be carried out routinely during the operations phase by MAP in-orbit.

2.2.3 The Cloud Imager (CLIM) on CO2M

The accuracy of the retrieved XCO2 strongly depends on the accurate knowledge of the effective light path. The presence of clouds can significantly alter the light path leading to systematic errors. Thus, the CO2 monitoring mission will use simultaneous measurements from a dedicated cloud imager (CLIM) to detect clouds, particularly in those categories, and filter CO2 data for cloud-contaminated cases.

The CLIM instrument is a three-channel imager with a spatial resolution of around 100 m in the visible and near infrared channels at 670 and 753 nm, and a spatial resolution of around 300 m for its SWIR channel around 1.3 micron.

The visible and NIR channel can be used to detect water clouds, while the 1.3 micron channel is suitable for the detection of high cirrus clouds.

The spectral band CLIM-2 (0.753µm) is spectrally overlapping with the NIR band of the primary observation (i.e., from CO2IS) and MAP, offering thereby the possibility to co-register

observations by image correlation methods and to validate the pointing accuracy and geolocation products of the MAP and CO2I/NO2I. In turn, CLIM-2 can be calibrated radiometrically by using the CO2I high spectral resolution NIR band.

2.3 The CO2M orbit

All CO2M platforms will fly on a 14+5/11 Sun-Synchronous orbit (SSO), with 11:30 mean local time at descending node.

Table 2.3: CO2M orbit definition

Repeat cycle	11 days
Cycle length	159 orbits
MLST at DNX	11:30
Altitude over WGS84 ellipsoid	739.6 to 766.9 km

In case of a three platform constellation the platforms will be phased consecutively in-orbit at 2/11 orbit separations: a central satellite preceded and followed by satellites at +/- 2/11 orbit separations, corresponding to +/- 65.45 deg / 18.11 min in-orbit [TBD]. Such a constellation will achieve Earth coverage above 40 degree latitudes within 2 days (and full coverage within 5 days) [TBD].

Figure 2.2 displays one CO2M orbit with indicative swath width for all three instruments.

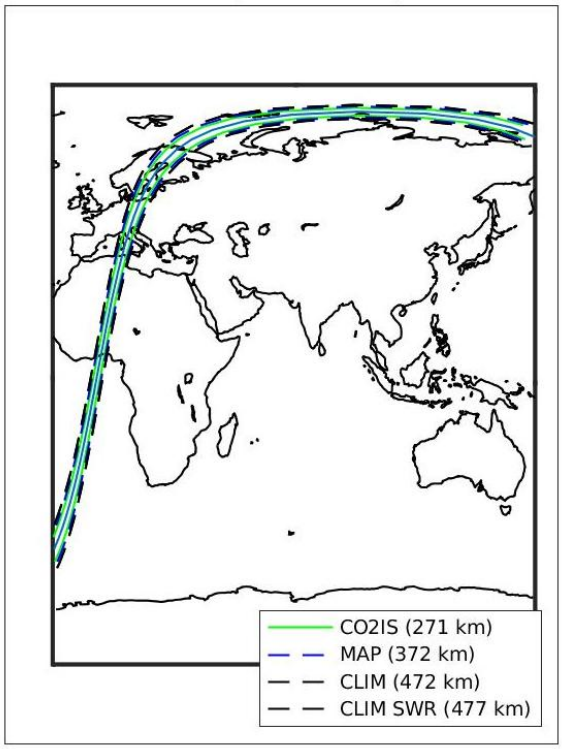

Figure 2.2: CO2M platform orbit with the main spectrometer (CO2IS), the MAP and Cloud Imager (CLIM) swath.

2.3.1 CO2M constellation

Figure 2.3 shows two times three orbits for a constellation of three CO2M platforms at different days: a constellation of three platforms with a separation of +/- 2/11 passing over Europe and a constellation of three platforms passing over Central Asia and Africa. For all three platforms, the swath width footprints are shown. Two platforms are shown *without* additional sun-glint steering and one, the West-orbit, *with* additional pitch steering, resulting in increased swath projection and larger spatial footprints on ground for the latter towards higher latitudes.

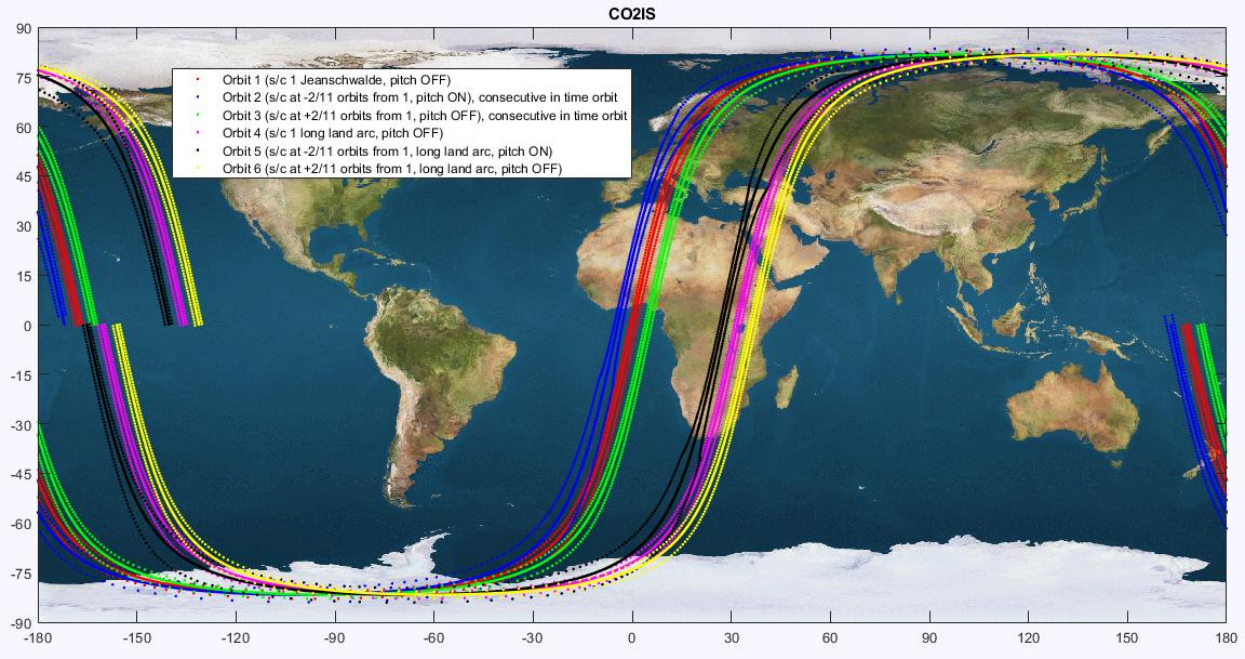

Figure 2.3: CO2M orbit simulations. Sub-satellite point and outer swath edges for six orbits of CO2M. The west orbit of each triple is flown with continuous pitch attitude control turned on.

2.4 Payload Data Ground Segment

2.4.1 The EUMETSAT CO2M Mission Data Processing Sub-Segment

The CO2M Mission Data Processing Sub-segment (MDPS) is part of the CO2M Payload Data Ground Segment (PDGS) part of the overall CO2M Ground-Segment. The Products Data Processing (PDP) infrastructure is providing the platform, the data-handling and the interface to the individual Instrument Processing Facilities (IPF) for product processing of all levels of products (Figure 2.4).

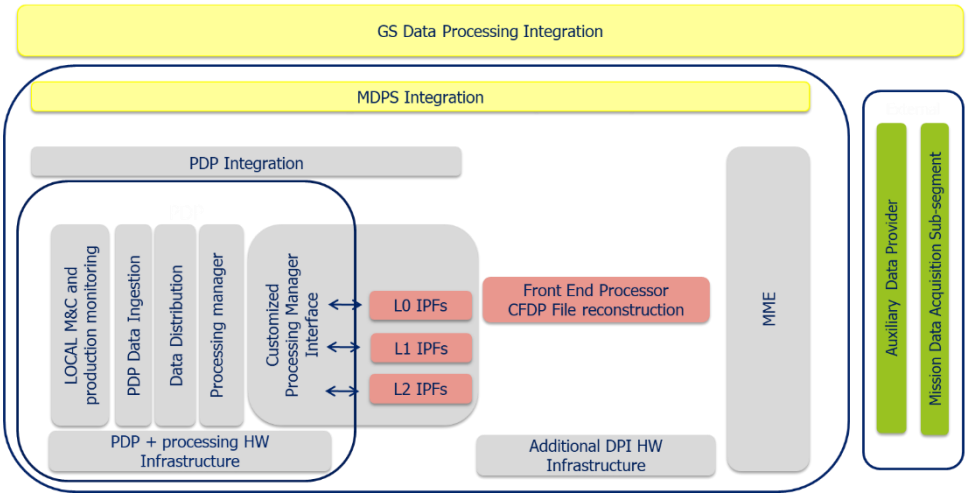

Figure 2.4: Schematic of the building blocks of the CO2M Mission Data Processing Sub-segment (MDPS) as part of the CO2M Ground Segment. The Product Data Processing (PDP) infrastructure is providing the platform, the data-handling and the interface to the Instrument Processing Facilities (IPF) for product processing of all levels up to level-2.

2.4.2 CO2M Product generation chain

Figure 2.5 provides an overview of the scientific processing tasks and their inter-dependency in the CO2M MDPS. The main user product output is produced in the last processing steps GHG-L2/MAP-L2 (XCO2, XCH4, and aerosol properties), and NO2-L2 (tropospheric NO2 column).

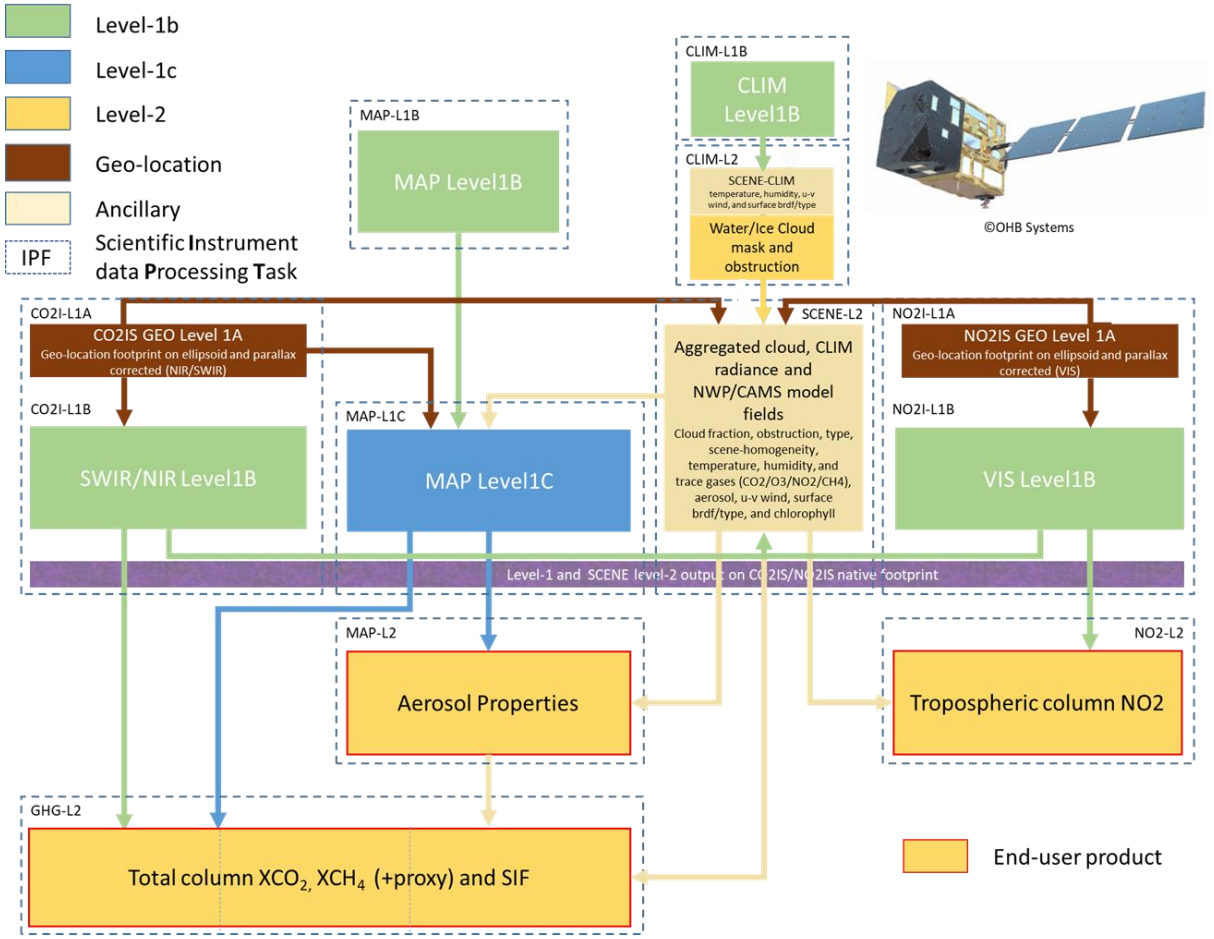

Figure 2.5: Schematic outline of all scientific instrument processing tasks (dashed boxes) in the MDPS for level-1 and 2. The FOCAL IPF will be one of three processors executed as part of the overall GHG-L2 multi-algorithm processing task with input from the CO2I level-1B, MAP-L1C, MAP-L2 and SCENE-L2 processing tasks.

2.4.3 CO2M Continuous Cal/Val and monitoring function

The Continuous Cal/Val and Monitoring function (C-CVMF) carries out the continuous Cal/Val and monitoring tasks on the CO2M products. While Cal/Val may require a considerable amount of time for gathering enough statistics from both on-ground as well as in-orbit data, continuous monitoring should be capable to identify deviations from the norm (being the last calibration and validation status) in near-real time. The Continuous Cal/Val and Monitoring Plan (C-CVMP) will specify the required data-sets and their availability as well as provides a schematic for data-flows and processing needs for both tasks. C-CVMF will be implemented on the existing principal architecture of the EUMETSAT operational Multi-Mission Elements (MME) for operational Monitoring and Cal/Val providing rolling archives of all MDPS data, processing power and large data-base capacities, along with automated and

user driven direct access to data-flows and databases for user-driven and automated reporting and monitoring.

Essential pre-processing functionalities before ingestion into the C-CVMF database (DB) are the ingestion and preparation of data, the co-location and/or co-registration of data to the target geo-reference grid (here the CO2M XCO_2/XCH_4 product footprint) and potentially additional pre-processing steps where needed.

2.4.4 CO2M product validation, verification and monitoring needs

Main user product validation is carried out at regular intervals, as well as continuously for the purpose of monitoring its validity (verification). Continuous product performance monitoring is also carried out for the purpose of monitoring the sensor and processor stability, as well as the occurrence of anomalies. Ground-based network data is therefore used for the following purposes for CO2M product validation, verification and monitoring in the overall CO2M Cal/Val operational system:

I. Product validation (validation - at regular intervals);
II. Product validation status monitoring (continuous verification);
III. Instrument and processing anomaly monitoring (continuous monitoring).

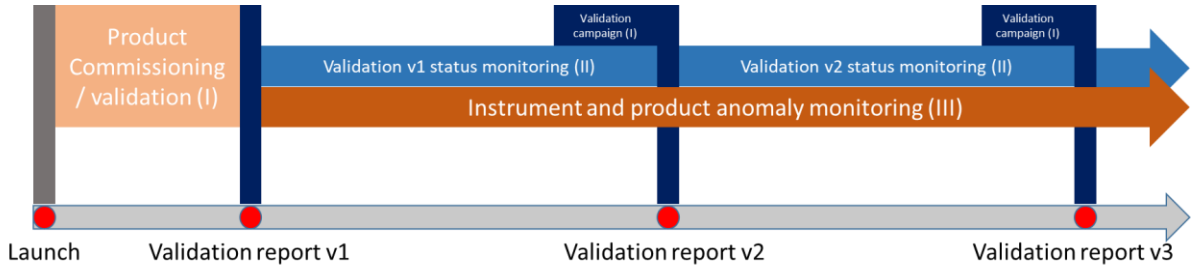

Figure 2.6: Schematic of CO2M product validation and associated campaigns (dark blue), continuous verification (light blue), and continuous monitoring (orange).

Data quality status and data provision of ground-based network data products (GBP) linked to objectives I to III are therefore:

A. High level ("level-2") of data quality maturity with high data availability and data provision timeliness >1 year
B. Medium level ("level 1.5") of data quality maturity with medium data availability and provision timeliness < 1 week (threshold) / 2-3 days (goal).

The mapping of ground-based network data performance and availability with respect to the CO2M validation objectives I to III is provided in Table 2.4

Table 2.4: Mapping of CO2M product validation and monitoring objectives and ground based data maturity, timeliness and availability.

CO2M product validation, verification and monitoring objective	Ground based network data maturity, timeliness and availability
I	A
II	B
III	B

3 CO2M USER PRODUCT REQUIREMENTS

The following sections detail the CO2M user product requirements in terms of product performance, availability and validation according to [SRD].

These requirements are provided for reference.

3.1 Product Performance

[SRD] DES.0215

All requirements of the CO2M System shall be met up to an SZA of 70 degrees, with performance characterised up to 80 degrees.

[SRD] DES.0220

The XCO2 level-2 Product service shall be provided during the operational lifetime of CO2M.

The systematic error of the XCO2 products shall not exceed 0.5 ppm for observations fulfilling the following conditions:

- Swath width >= 250 km and ground sample areas with solar zenith angle (SZA) < 70 deg;
- radiance levels within the dynamic range limits specified in [MRD];
- cloud free, up to the detection limit of the CO2M System;
- aerosol optical depth (AOD) of observation < 0.5.

A precision < 0.7 ppm shall be met for a vegetation scenario (as per [MRD]) at SZA = 50 degrees.

The requirement shall apply to individual observations with a spatial resolution <= 4 km2, aspect ratio (AR) 0.5 <= AR <=2, with no zonal or temporal averaging applied.

[SRD] DES.0230

The NO2 tropospheric vertical column level-2 Product service shall be provided during the operational lifetime of CO2M.

The systematic error of the NO2 tropospheric vertical column products shall not exceed 3.5 10^{15} molec/cm^2 for observations fulfilling the following conditions:

- radiance levels within the dynamic range limits specified in [MRD]
- cloud coverage of observation < 50 %;
- aerosol optical depth (AOD) of observation < 0.5.

A precision < 1.5 10^{15} molec/cm^2 shall be met for observations fulfilling the following conditions:

- SZA = 0 deg;
- reference scenario (as per [MRD]).

The requirement shall apply to individual observations. In case of a spatial over-sampling of the NO2 sampling grid with respect to the CO2 grid the Level 2 relevant performance shall be met for the CO2 grid.

[SRD] DES.0240

The following service shall be provided during the operational lifetime of CO2M: XCH4 level-2 Products:

- Swath width >= 250 km and ground sample areas with solar zenith angle (SZA) < 70 deg;

The systematic error of the XCH4 products shall not exceed 5 ppb as a target for observations fulfilling the following conditions:

- radiance levels within the dynamic range limits specified in [MRD];
- cloud free, up to the detection limit of the CO2M System;
- aerosol optical depth (AOD) of observation < 0.5.

A precision < 10 ppb is targeted for a vegetation scenario (as per [MRD]) at SZA = 50 degree

The requirement shall apply to individual observations with a spatial resolution <= 4 km2, aspect ratio (AR) 0.5 <= AR <=2, with no zonal or temporal averaging applied.

[SRD] PER.0130

The CO2M System shall make the XCO2 data products available to end users within 24 h after sensing.

[SRD] PER.0140

The CO2M System shall make the NO2 data products available to end users within 24 h after sensing.

[SRD] PER.0170

The CO2M System shall make the XCH4 products available to end users within 24 h after sensing

3.2 Aerosol properties requirements

For CO2M aerosol and cloud information needs to be derived with a precision and systematic error such that the main XCH4, XCO2 and NO2 products can be retrieved with a performance according to DES.0220, DES.0230 and DES.0240 [SRD].

[SRD] DES.0250

Aerosol and cloud information as needed for optical path length corrections in the CO2I spectral bands shall be systematically generated.

This will require systematic error and precision for the CO2M aerosol product (MAP L2) as provided in ***Table 3.5***.

Table 3.5: Aerosol properties requirement for parameters retrieved from measurements of the Multi Angle Polarimeter (MAP) on-board CO2M.

Aerosol property	Precision	Systematic error
Aerosol Optical Depth	<0.04 or 10% (whatever is bigger)	<0.02
Angstrom exponent	<0.3	<0.2
Single scattering albedo	<0.03	<0.02

Note: These requirements have to be fulfilled at all wavelength provided by the Multi Angle Polarimeter (MAP) measurements: ie., at 410, 443, 490, 555, 670, and 865nm.

3.3 Availability

[SRD] RAMS.0200

The System availability shall be better than 95% on the monthly basis, taking in account:
- Space segment availability: 97 %;
- FOS mission control system: 99.9 %;
- PDGS TM acquisition & Level 0 availability: 98 %.

The requirement shall apply to individual satellites in case of a of multiple satellite constellation.

3.4 Validation

[SRD] CV.0130

The system shall provide for all the instruments continuous validation and monitoring of the full production chains and generated products.

4 GROUND-BASED NETWORK PRODUCT REQUIREMENTS FOR CO2M

The following requirements target the use of total column (dry-air column-averaged mole fraction of CO2, CH4, and the tropospheric column of NO2), and aerosol properties ground-based network measurement data with the required product quality performance, availability and timeliness to serve the needs of the CO2M product validation, verification and monitoring as specified in Section 2.4.4. The following key-performance indicators are relevant in this respect:

I. Ground-based network product performance (Section 4.1)
   a. Product systematic error
   b. Product precision
II. Ground-based network product availability (Section 4.3)
III. Ground-based network product timeliness (Section 4.2)

These ground-based network data requirements will satisfy the SRD validation requirement [SRD] CV.0130 (Section 3.4) separated into threshold (T) and goal (G) achievements.

4.1 Product performance

Requirements on overall precision

GDAT-0010	The precision of the ground-based XCO2 product shall be better than 1 (T) / 0.5 (G) ppm.
GDAT-0020	The precision of the ground-based tropospheric NO2 product shall be better than 1.5 10^{15}molec/cm^2 or 15% (T) / 0.5 10^{15}molec/cm^2 or 5% (G).
GDAT-0030	The precision of the ground-based XCH4 product shall be better than 10 (T) / 2.5 (G) ppb.
GDAT-0040	The precision of the ground-based aerosol optical depth product shall be better than 0.04 (T) / 0.03 (G) or better than 10% (T) / 5% (G) whatever is bigger.
GDAT-0041	The precision of the aerosol Angstrom exponent product shall be better than 0.3 (T) / 0.2 (G).
GDAT-0042	The precision of the aerosol single scattering albedo product shall be better than 0.03 (T) / 0.02 (G).

Note, that requirement GDAT-0040, GDAT-0041, GDAT-0042 shall be met at 410, 443, 490, 555, 670, and 865 nm.

Requirements on overall systematic error

GDAT-0050	The systematic bias of the ground-based XCO2 product shall be better than 0.7 (T) / 0.5 (G) ppm.

GDAT-0060	The systematic bias of the ground-based tropospheric NO2 product shall be better than 3.0 10^{15} molec/cm^2 or 30% (T) / 1.5 10^{15}molec/cm^2 or 15% (G).

GDAT-0070	The systematic bias of the ground-based XCH4 product shall be better than 15 (T) / 5 (G) ppb.

GDAT-0080	The systematic bias of the ground-based aerosol optical depth product shall be better than 0.02 (T) / 0.01 (G).

GDAT-0081	The systematic bias of the aerosol Angstrom exponent product shall be better than 0.2 (T) / 0.1 (G).

GDAT-0082	The systematic bias of the aerosol single scattering albedo product shall be better than 0.02 (T) / 0.01 (G).

Note, that requirement GDAT-0080, GDAT-0081, GDAT-0082 shall be met at 410, 443, 490, 555, 670, and 865 nm.

4.2 Product timeliness

Requirements on ground-based product timeliness

GDAT-0100	The ground-based network shall make the data products available to the EUM CF within 1 week (T) / 3 days (G) after sensing.

4.3 Product availability

Requirements on ground-based product availability

GDAT-0200	The ground-based network data availability shall be better than 80 % of the CO2M constellation platform station "overpasses", under cloud-free conditions at the site, and within an area around the station as specified by (1). The availability is calculated within an observation time window of the CO2I/NO2I instrument sensing time, per platform, of +- 1 h.

(1) The reference number of overpasses (i.e. the ground-based measurement station being in the visibility of the CO2I/NO2I instrument for SZA<80 degrees) is provided per station and per CO2M platform in Appendix A.

APPENDIX A REFERENCE OVERPASS STATISTICS PER GROUND-BASED NEWTORK STATION FOR THE CO2M CONSTELLATION.

Current estimated CO2M constellation overpass statistics given a specific footprint per station is evaluated for currently available stations following methodologies outlined in [STA]

Data is available and summarized in the dedicated CO2M ground-based station database [DAT]. The data is accessible via

http://co2m.aeronomie.be