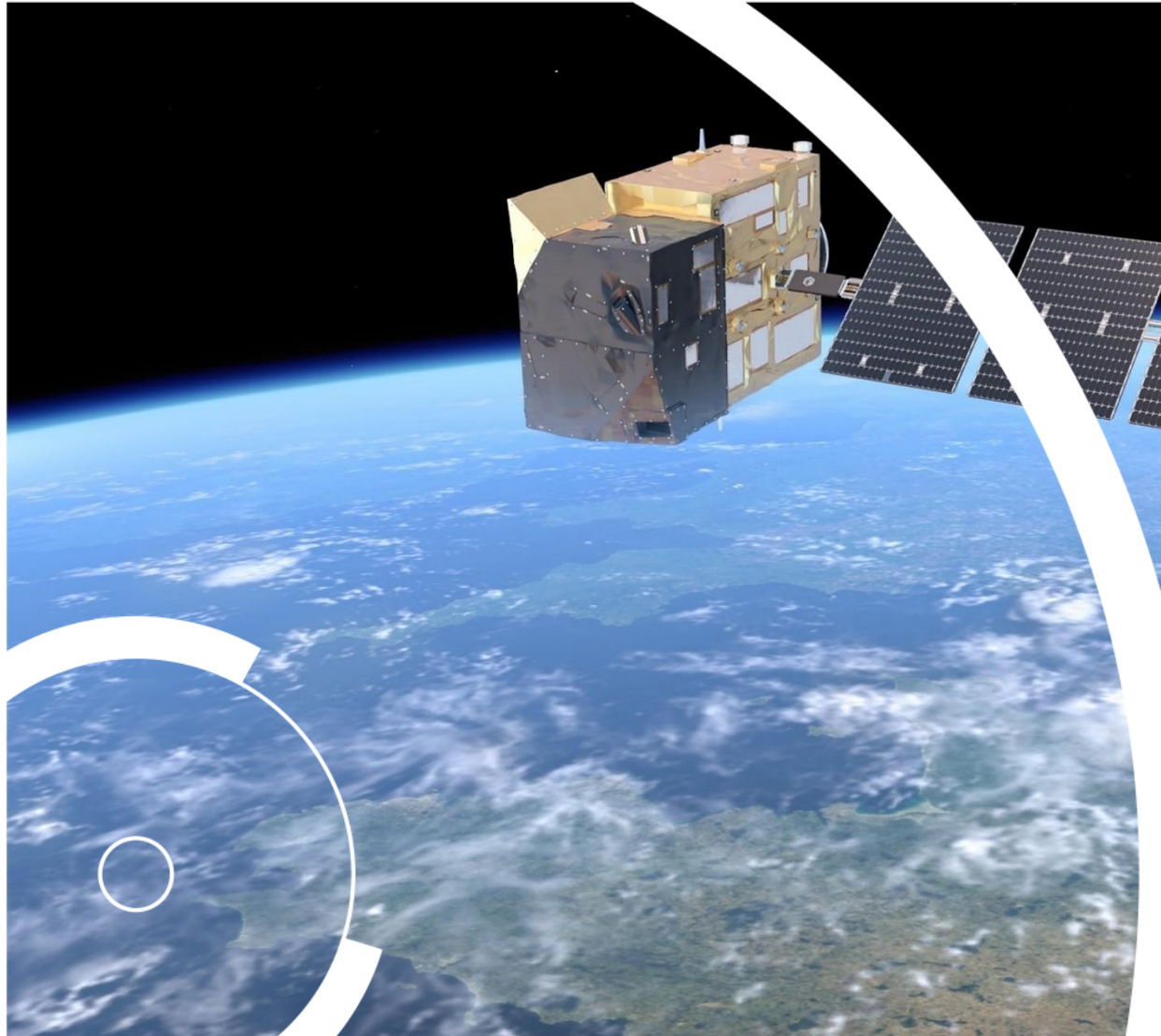




AC-VC-22 meeting

6.16

CO2M validation network update

4 June 2026



Ruediger Lang, Catherine Hayer, Thierry Marbach, Hannah Clarke, Bojan Bojkov, Maurizio De Bartolomei, Helmut Bauch, Bojan Bojkov, Leonid Butenko, Paola Colagrande, Josef Gasteiger, Philipp Heinen, Bernd Husemann, Antoine Lacan, Fabrizio Di Loreto, Remy Perin, Pepe Phillips, Cosimo Putignano, Vincenzo Santacesaria, Sruthy Sasi, Bernd Sierk, and Eduardo Valido Cabrera

Mahesh Kumar Sha, Michel Kruglanski, Bavo Langerock (BIRA-IASB), Matthias Buschmann (MBER), Arndt Meier, Frank Hase (KIT)



Three satellite missions each with a 270 km swath:

- ✓ Providing greenhouse-gas data for the Copernicus GHG Monitoring and Verification Support capacity
- ✓ Launch: End 27 / Beg 28 / Mid 29

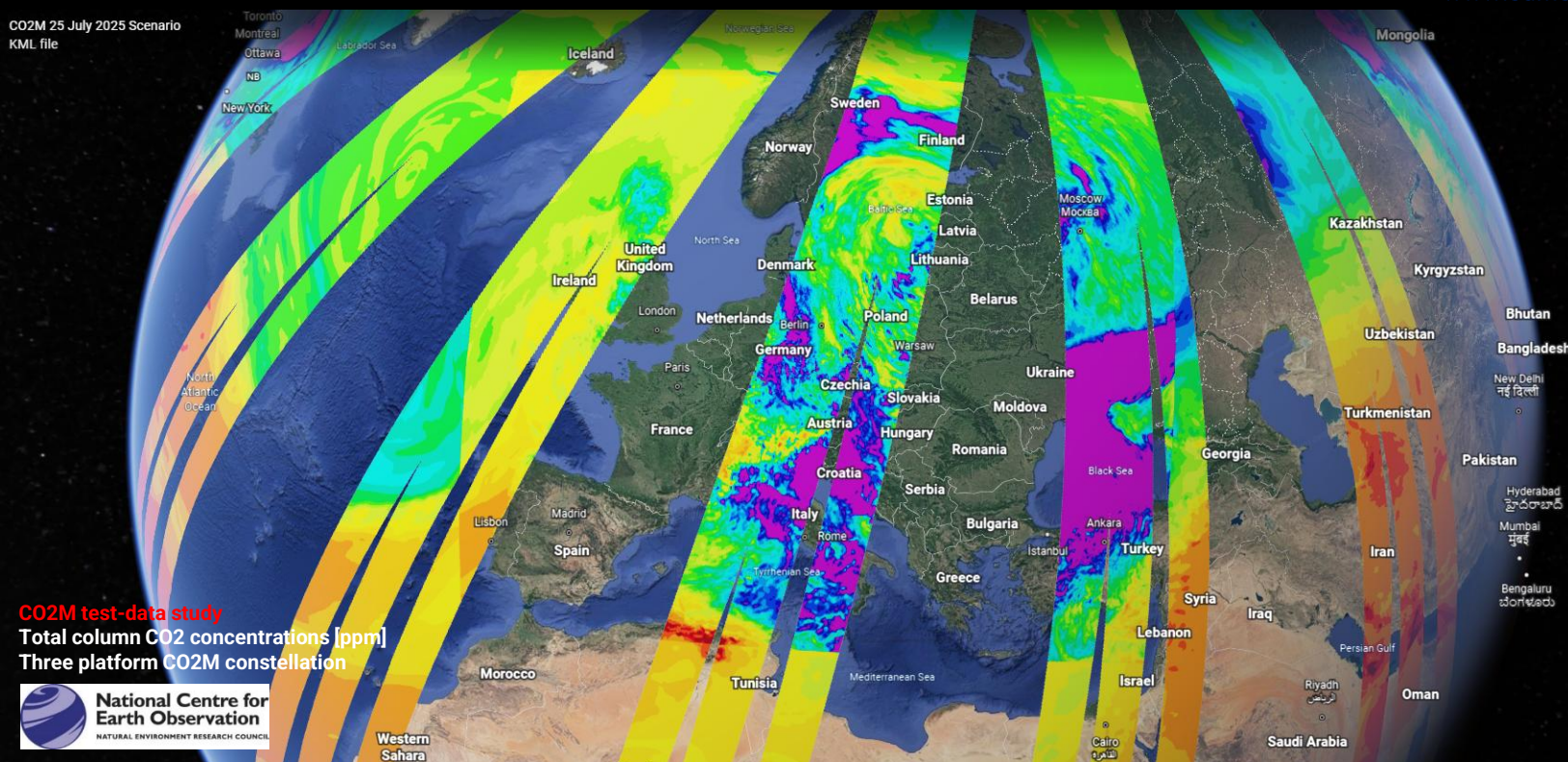
Three instruments per platform:

- CO2/NO2 push-broom grating spectrometer (CO2I/NO2I)
- Multi-Angle Polarimeter (MAP)
- Cloud Imager (CLIM)

Orbit:

- Sun-synchronous orbit 14 5/11
- 159 orbits repeat cycle (~11 days)
- 735 km altitude
- 11:30 LT
- Platforms in same orbital plane

CO2M 25 July 2025 Scenario
KML file



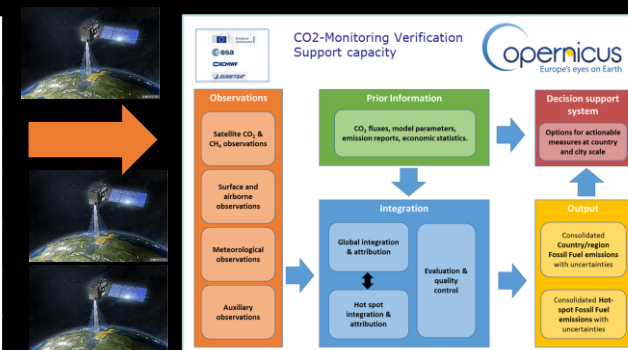
CO2M test-data study
Total column CO2 concentrations [ppm]
Three platform CO2M constellation



End user products:

Product	Spatial resolution	Precision	Bias
CO2	4 km ²	0.7 ppm	<0.5 ppm
CH4	4 km ²	10 ppb	<5 ppb
NO2	4 km ²	1.5x10 ¹⁵ molec/cm ²	<3.5x10 ¹⁵ molec/cm ²
SIF*	4 km ²	0.7 mW m ⁻² sr ⁻¹ nm ⁻¹	<0.2 mW m ⁻² sr ⁻¹ nm ⁻¹
Aerosols	16 km ²	0.05 AOD, 500 m LH	<0.05 AOD, 500 m LH
Clouds	4 km ²	<1% of FOV	

*Solar Induced Fluorescence



WG-climate (CEOS/CGMS) and WMO-G3W GHG road-map targets

Contribution by CO2M Cal/Val developments



- ❖ To **create interoperable ground-based GHG reference L2 products** (e.g., column-integrated CO₂ and CH₄ dry air mole fractions, XCO₂, and XCH₄ and other geophysical parameters) the retrieved estimates derived from different sensors must be cross-validated against internationally accepted standards (e.g., TCCON, COCCON, NDACC, AirCore).
- ❖ To support **services with low latency requirements**, the timely **availability** of the surface-based validation data needs to be improved. These products must be operationally delivered to organizations, such as GHG MVS services, that combine the GHG concentration estimates.
- ❖ It is also of high importance that these products, along with their **uncertainties, must be documented** so that they can be harmonized with other available surface-based, and airborne, products used for validation.
- ❖ **CEOS and CGMS** organizations play a critical role in **developing and coordinating truly operational interoperable products** from multiple missions spanning space-based GHG measurements.

The accumulation of significant and representative statistics during the course of product commissioning (and to be continued thereafter) is of highest priority:

- To discriminate the different bias contributors
- To make biases emerge from noise

Means:

- ***Priority on continuous collection of reference data with high automation, low human resource need and low carbon cost***
- Significant contribution of in-flight accumulated reference data (vicarious statistical, and/or from stable well-known targets)
- Re-use of existing operational validation and monitoring environments (see next slides)
- Methodologies and capabilities are developed as part of individual product science support services, including two dedicated Cal/Val studies
- Dedicated validation support teams are currently put in place per product (Cal/Val plan updated section on roles and responsibilities – see below)
- Dedicated campaign opportunities and associated data - as available

On-board Cal:

Source	C02I	MAP	CLIM	Frequency
SUN	X	X		daily
Moon	X	X	X	Irreg.
WLS	X			weekly
Tuneable LED	X (ISRF)			
Dark	X	X	X	orbit

CGMS-GSICS

Vicarious Cal “as needed”



CO2M
0.3 nm (@1.6 μ m)

- SNOs
- Ref. Targets
- etc.

Cross-Cal



MicroCarb, OCO-x, GOSAT-x, S5, etc.

~0.05 nm (@1.6 μm)

CGMS-GSICS



CO2M Cal/Val Phase II

(including GBP processing and data delivery) (KO: Q3 2024)

Scientific support service on ground-based product requirements (LMU) Phase I

Scientific support service on ground-based network product processing (KIT)



PaNIR
2.5 nm (@1.6 μm)

Scientific feasibility study for PaNIR



COCCON
0.14 nm (@1.6 μ m)



Cross-Cal



TCCON
0.005 nm (@1.6 μm)

Spectrally oversampled
reference

Similar spectral resolution

“Four-pillar” CO2M operational product validation and monitoring space-to-ground and space-to-space approach

+ NDACC- FTIR CH₄ + Pandonia/NDACC NO₂ + Aeronet for AOD + Galion for Aerosol profiles

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Source	CO2I	MAP	CLIM	Frequency
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CGMS-GSICS

Product VAL

Product Cal/Val

Product Cal/Val

Product Cal/Val

Cross-Cal

Cross-Cal

Spectrally oversampled
reference

Similar spectral resolution



PaNIR
2.5 nm (@1.6 μ m)



COCCON
0.14 nm (@1.6 μ m)



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0.005 nm (@1.6 μ m)

"Four-pillar" CO2M operational product validation and monitoring space-to-ground and space-to-space approach

+ NDACC- FTIR CH4 + Pandonia/NDACC NO2 + Aeronet for AOD + Galion for Aerosol profiles

Develop a controlled ground-based reference data provision service and establish a solid link with ground-measurement networks.

- ***no more ad hoc approach per mission but rather a global service approach.***
- EUMETSATs priority is therefore to **implement an operationally resilient infrastructure serving CO2M with ground-based reference data**, plus additional Cal/Val support capacities to prepare and to carry out CO2M product commissioning.
- ❖ **Recall:** the existing Copernicus program initiatives (e.g. for NDACC data-service to CAMS) principally work on a **service-based** approach for the provision of ground-based data products, which are provided under certain criteria (timeliness, availability, quality) and without direct funding of the measurements, observations, nor staff directly.
 - i.e., funding of the operations and measurement infrastructure must, in most cases, come from other (e.g., national) sources.



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THE EUROPEAN UNION



A new CO2M Cal/Val (preparation) service has been kicked off in June 2025
(BIRA/MBER/S&T/iLab)



Tasks:

- ❖ **Prepare commissioning** activities for use of ground-based reference data (GBD)
- ❖ Prepare and carry out the **management and contractual framework to receive ground-based reference data** according to the requirements and against a data provision service fee
- ❖ **Interaction with TCCON, COCCON and NDACC PIs** and community has been and will be regularly updated on progress
 - Network PIs are invited to the PMs after network call in April 2026
- ❖ **Network call for data-provision service** (“ground-based data provision service”) under CO2M Cal/Val GBP requirements is - **21st April 2026 21:00 – 23:00 CEST**.

In collaboration with:

- ❖ **Scientific support service on ground-based network product processing**
 - See next presentation for details







Ground-based data processing for CO2M product Cal/Val “towards operations”

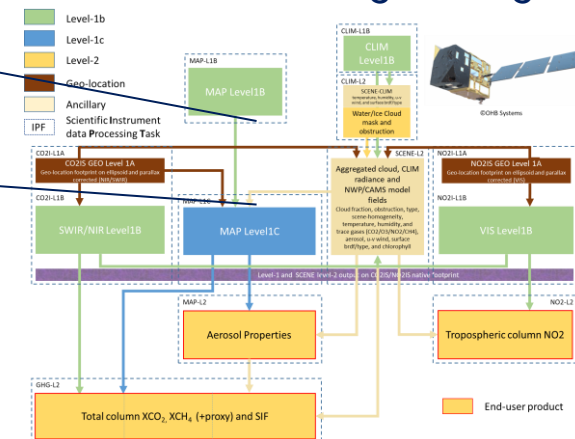
www.eumetsat.int

“SCENE for GDP”

TCCON/COCCON network
prior data (GEOS-FPIT, ...)

CO2M a-priori and auxiliary
data products

EUMETSAT Mission Data Processing Sub-segment



Prior-data processing

MBER

Station specific configuration



Site specific ground-based upload folders

Checks regularly for new data

move data

data archive (raw + processed)

CO2M tailored products

GBP

gbp_lib core application

output-manager (netCdf)

get processed data

Streamlit server (websocket comm.)

(optional) Graphical UI

job launch

job live view

job kill button

data exploration

A-priori manager

handles each step to the

Process supervisor

monitors

updates

creates job

Model atmosphere from GEOS-FPIT or CAMS/SCENE

TCCON processor (GGG2020)

or

COCCON processor (PROFFAST)

GBP-DB (postgresql) db server

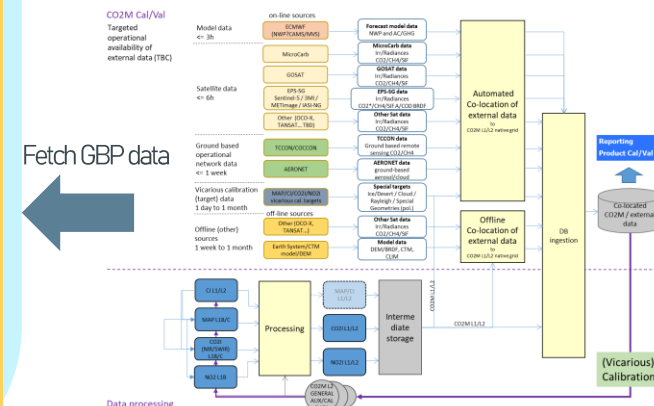
CO2M-GDP Level-2
aim:
timeliness < 1 week

TCCON/COCCON Level-2 fiducial reference data (aim: timeliness < 2 month)

Network data (GBP) level-1 and 2 archive

s&t

EUMETSAT Cal/Val Facility





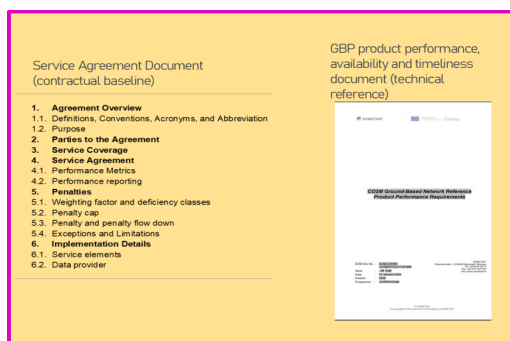
Call for ground-based reference CO₂ and CH₄ data provision service in support of Copernicus CO₂M Validation

www.eumetsat.int

Contractual service framework for GBP data-provision service:

Royal Belgian Institute for Space Aeronomie (BIRA-IASB) is tasked by EUMETSAT on behalf of the European Commission with implementing a data provision service to the EUMETSAT operational Cal-Val facility comprising fit-for-purpose data of dry-air column weighted abundances of Carbon Dioxide and Methane (XCO₂ and XCH₄) from ground-based solar absorption measurements satisfying a number of criteria as outlined in the following.

<https://co2m.aeronomie.be/gb-rdp-copernicus-co2m-validation>



Service level agreement between Station PI and BIRA-IASB

Station data according to

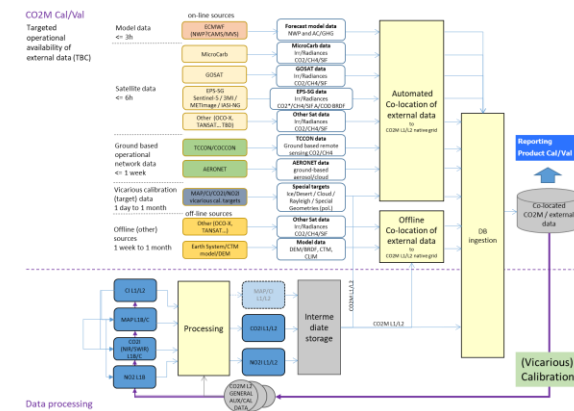
- 1) Service Level agreement conditions
- 2) Product performance conditions

Service fee per data-unit satisfying SLA and GBP requirements

Station data of various types from BIRA/MBER to EUM

Re-funding of service fees to BIRA from Copernicus via EUM WP

EUMETSAT Cal/Val Facility



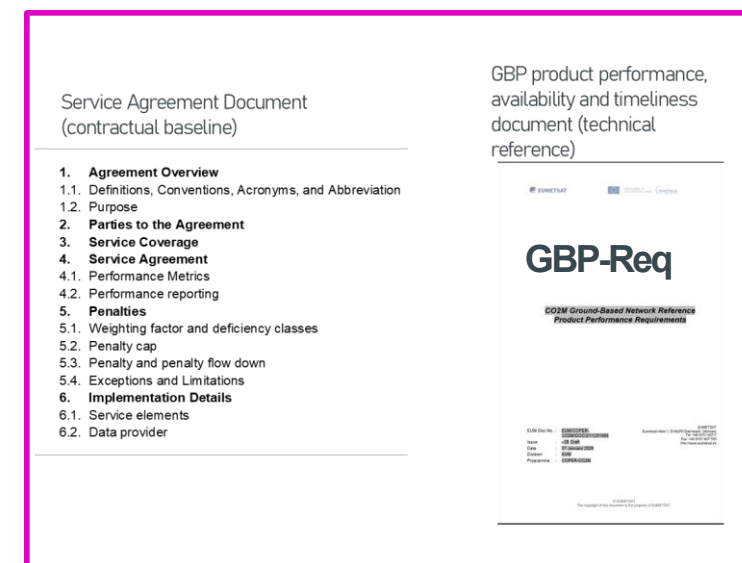
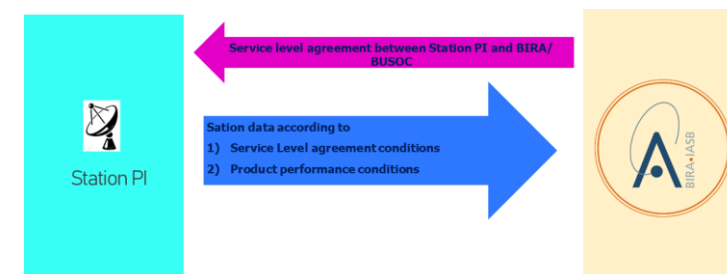
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Copernicus
Europe's eyes on Earth

The following measurement and instrument types and associated data products are eligible for support (non exclusive!):

Measurement Technique	target		
	Level 0/1	Level-2 Total column	Level-2 Profile
NIR-FTS	Slices or Interferograms (L0) Spectra (L1)	XCO ₂ , XCH ₄	
MIR-FTS	Interferograms (L0) Spectra (L1)		CH ₄ profile with min 2 dofs / XCH ₄
Auxiliary data (from all FTS networks)	Surface pressure Measurement condition flag Temperature (optional) Humidity (optional) Wind speed (optional) Wind direction (optional) Cloud information (if available)		

1. Timeliness of **incoming level-2 products** shall be better than **1 week (threshold) / 3 days (goal)** for network approved reference data.
 2. Timeliness of incoming **level-0/1 data** (if provided) shall be better than **3 days**.
 3. **Availability** of data shall be better than **80%** out of the number of potentially available **cloud free** measurements at the station.
 4. The product quality shall fulfil the product quality criteria in precision and accuracy as outlined in the CO2M Ground-Based Network Reference Product Performance Requirements document (**GBP-Req**).
- ❖ Note, the overpass times will be provided to all station providers as input.



Data Product Performance Requirements

www.eumetsat.int

Bruker IFS 125HR (TCCON)	XCO ₂	The precision of the ground-based XCO ₂ product shall be better than 0.5 ppm (1-sigma standard deviation across time windows varying between 2-6 hours at all solar zenith angles (SZA) < 82°) with single scans (no coadding) (target).
		The systematic bias of the ground-based XCO ₂ product shall be better than 0.5 ppm (mean absolute deviation against in situ coincident measurements available as of 2022 at all SZA < 82°) (target).
	XCH ₄	The precision of the ground-based XCH ₄ product shall be better than 2.5 ppb (1-sigma standard deviation across time windows varying between 2-6 hours at all solar zenith angles (SZA) < 82°) with single scans (no coadding) (target).
		The systematic bias of the ground-based XCH ₄ product shall be better than 5 ppb (mean absolute deviation against in situ coincident measurements available as of 2022 at all SZA < 82°) (target).
Bruker EM27/SUN or Bruker VERTEX70 or Bruker INVENIO, ... (COCCON)	XCO ₂	The precision of the ground-based XCO ₂ product shall be better than 0.15 ppm (1 min integration) (target).
		The systematic bias of the ground-based XCO ₂ product shall be better than 0.625 ppm (mean absolute deviation derived from TCCON calibration which is calibrated against in situ coincident measurements available as of 2022 at all SZA < 82°) (target).
	XCH ₄	The precision of the ground-based XCH ₄ product shall be better than 0.8 ppb (1 min integration) (target).
		The systematic bias of the ground-based XCH ₄ product shall be better than 6.25 ppb (mean absolute deviation derived from TCCON calibration which is calibrated against in situ coincident measurements available as of 2022 at all SZA < 82°) (target).
IFS 12x or Bomem DA8 (NDACC)	XCH ₄	The precision of the ground-based XCH ₄ product shall be better than 10 ppb (target).
		The systematic bias of the ground-based XCH ₄ product shall be better than 15 ppb (target).

EUMETSAT

MEMBER OF THE EUROPEAN SPACE INFRASTRUCTURE

**CO2M Ground-Based Network Reference
Product Performance Requirements**

EUM Doc No : EUM/COPERNICUS/CO2M/DOC/02/11251908
Issue : v08.01
Date : 07 January 2024
Division : EUM
Programme : CO2M/CO2M

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Status:

- We have already received initial “Expression of Interests” to participate in the service from quite a number of PIs/station.
- Eols are currently evaluated and Pis will receive feedback for the next iterations during summer

Next steps:

- Putting in place Service Level Agreements (SLAs) with individual PIs (and BIRA/BUSOC) by Q1 2027
- Start of pre-operational phase: 4 month before launch of 1st platform

The details of the call are available on:

<https://co2m.aeronomie.be/gb-rdp-copernicus-co2m-validation>

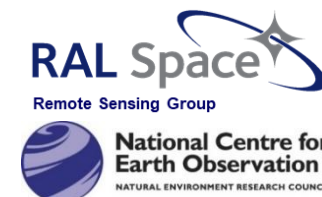
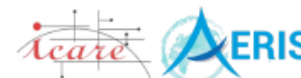
Thank you!



Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat



MBER



Overpasses, 1 year, all sites

Phase 2 XCO₂: 65 sites

platform	AOT	0-15 deg	15-30 deg	30-45 deg	45-60 deg	60-80 deg	Total
CO2Mcent	0.00-0.15	618330	1403473	1998087	2273140	1377526	7670556
CO2Mcent	0.15-0.30	240578	566417	460295	210430	60503	1538223
CO2Mcent	0.30-0.50	152494	200724	175689	89628	6767	625302
CO2Mcent	0.50-1.00	83977	111516	227845	86092	17344	526774
CO2Mcent	Total	1095379	2282130	2861916	2659290	1462140	10360855

Phase 2 NO₂: 736 sites

platform	AOT	0-15 deg	15-30 deg	30-45 deg	45-60 deg	60-80 deg	Total
CO2Mcent	0.00-0.15	2119	5230	5921	6705	4631	24606
CO2Mcent	0.15-0.30	1187	3195	2017	938	155	7492
CO2Mcent	0.30-0.50	643	1316	843	337	20	3159
CO2Mcent	0.50-1.00	492	562	410	198	41	1703
CO2Mcent	Total	4441	10303	9191	8178	4847	36960