EUMETSAT

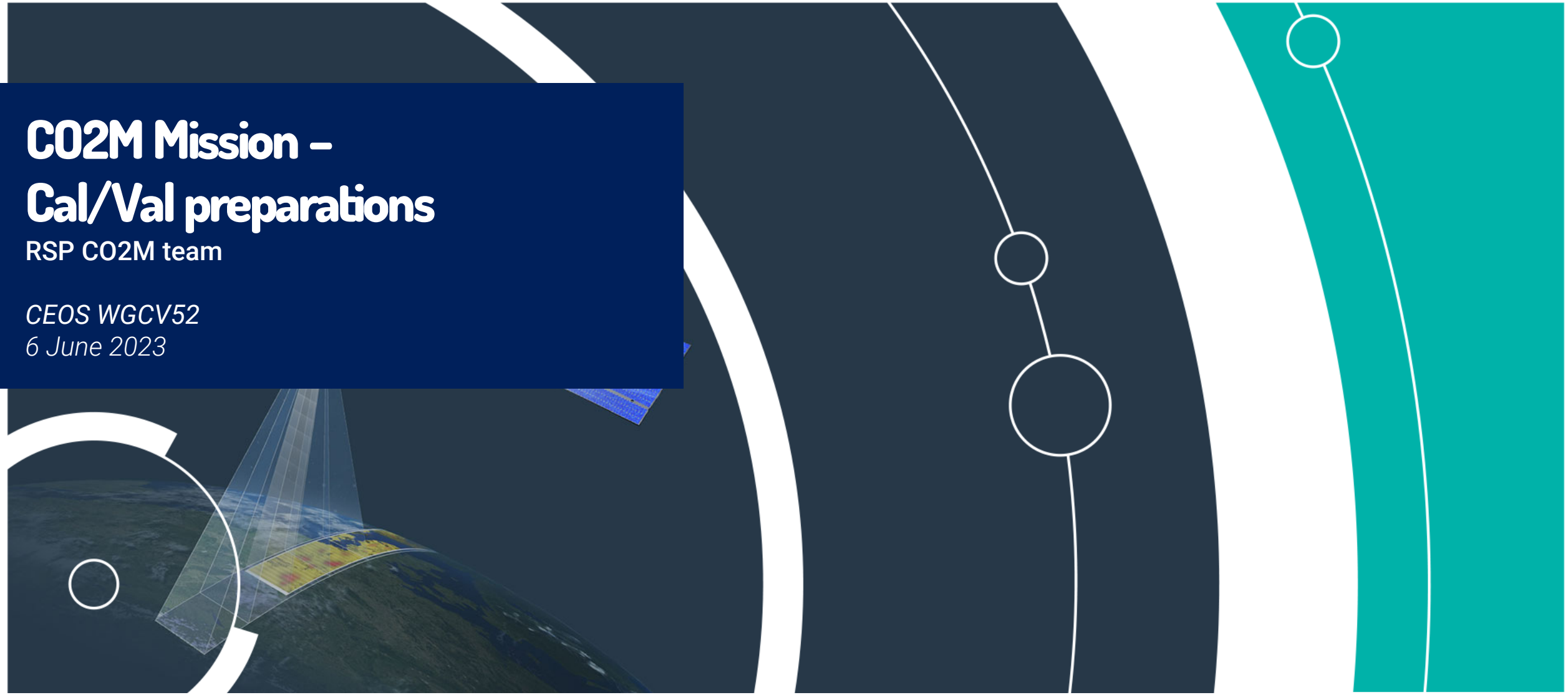
PROGRAMME OF THE EUROPEAN UNION

Copernicus
Europe's eyes on Earth

CO2M Mission – Cal/Val preparations

RSP CO2M team

CEOS WGCV52
6 June 2023



The CO2M greenhouse-gas monitoring constellation

copernicus.eumetsat.int

Three (TBC) satellite missions with each >250 km swath:

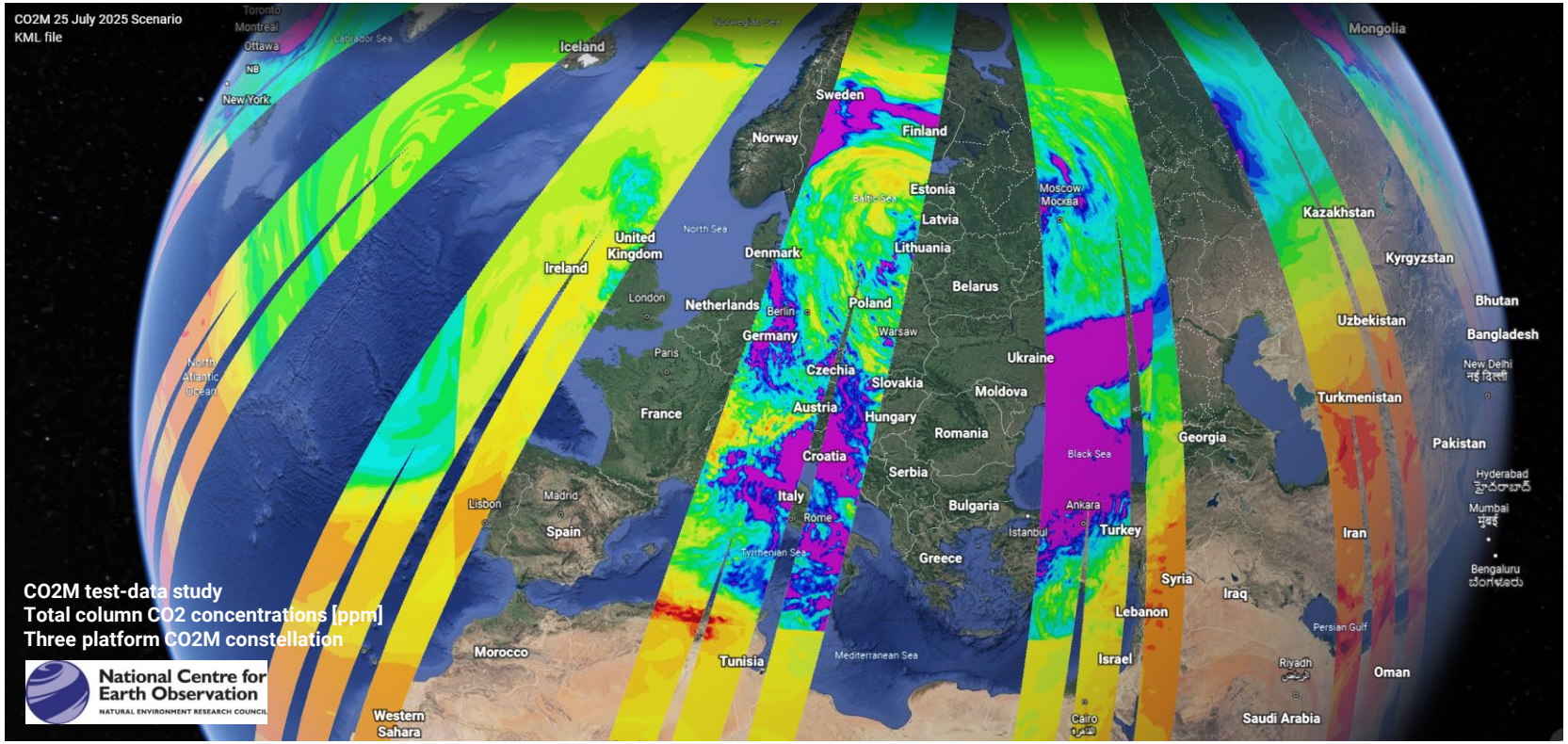
- FAR of Proto-flight Model (PFM) & Flight Model #2 (FM2) Q1 2026
- Launch of FM3 6 months after launch of PFM

Three instruments per platform:

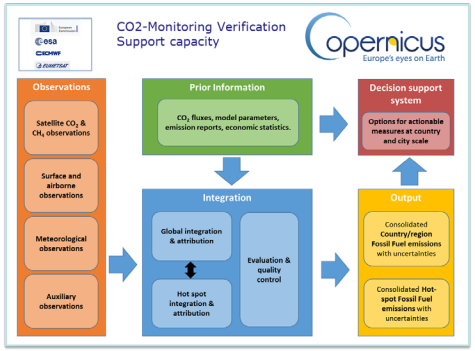
- CO2/NO2 push-broom grating spectrometer (CO2I/NO2I)
- Multi-Angle Polarimeter (MAP)
- Cloud Imager (CLIM)

Orbit:

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



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	



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EUMETSAT CO2M MDPS scientific processing tasks

CO2M
Mission Data
Processing System

Make one
“hyper-GHG/NO2-instrument”
out of three!

Level-1b
Level-1c
Level-2
Geo-location
Ancillary
IPF
Scientific Instrument data Processing Task

MAP-L1B
MAP Level1B

CLIM-L1B
CLIM Level1B

CLIM-L2
SCENE-CLIM
temperature, humidity, u-v wind, and surface brdf/type
Water/Ice Cloud mask and obstruction

CO2I-L1A
CO2IS GEO Level 1A
Geo-location footprint on ellipsoid and parallax corrected (NIR/SWIR)

CO2I-L1B
SWIR/NIR Level1B

MAP-L1C
MAP Level1C

SCENE-L2
Aggregated cloud, CLIM radiance and NWP/CAMS model fields
Cloud fraction, obstruction, type, scene-homogeneity, temperature, humidity, and trace gases (CO2/O3/NO2/CH4), aerosol, u-v wind, surface brdf/type, and chlorophyll

NO2I-L1A
NO2IS GEO Level 1A
Geo-location footprint on ellipsoid and parallax corrected (VIS)

NO2I-L1B
VIS Level1B

Level-1 and SCENE level-2 outputs on CO2IS/NO2IS native footprint

Below this level: everything is co-registered or provided at the CO2I/NO2I spectrometer footprint

MAP-L2
Aerosol Properties

NO2-L2
Tropospheric column NO2

GHG-L2
Total column XCO_2, XCH_4 (+proxy) and SIF

End-user product

Need for XCO2, XCH4 NO2 and AOD validation

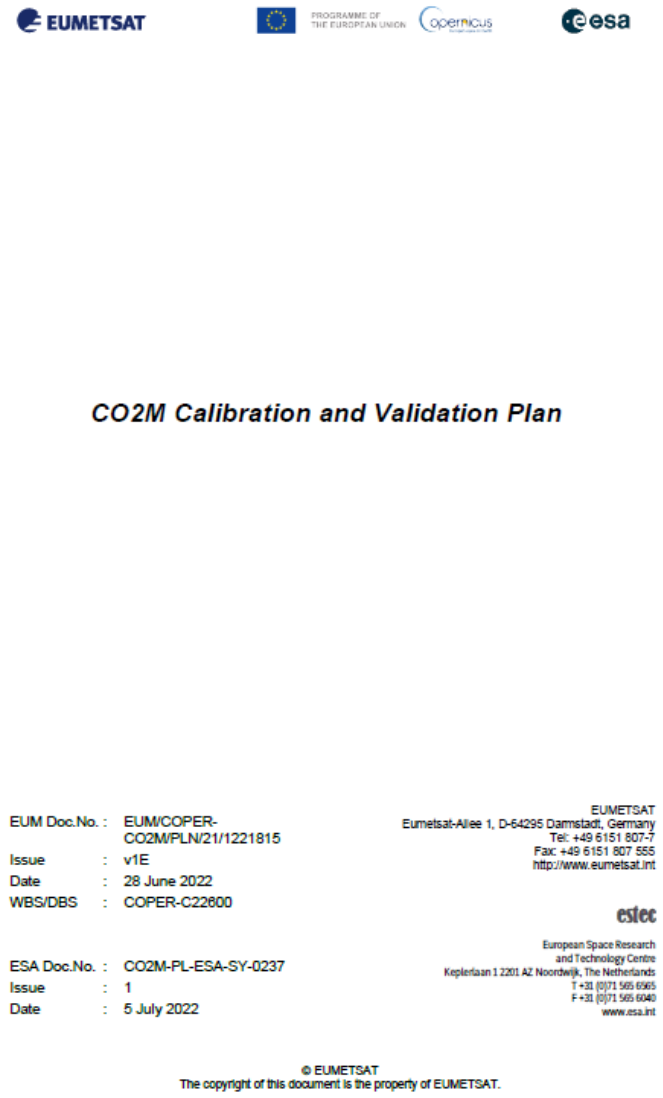
Scope of EUMETSAT CO2M Cal/Val plan:

- End-user product validation

(Different from ESA's satellite and instrument performanc Cal/Val plan for instrument commissioning!)

  - Involves calibration (level-1 processing) and validation of intermediate product performance

Version 1 of CO2M product Cal/Val plan available



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CO2M Calibration and Validation Plan

EUM Doc.No. : EUM/COPER-CO2M/PLN/21/1221815
Issue : v1E
Date : 28 June 2022
WBS/DBS : COPER-C22600

ESA Doc.No. : CO2M-PL-ESA-SY-0237
Issue : 1
Date : 5 July 2022

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EUMETSAT CO2M Cal/Val study:

Started 1st July 2021

Support definition of product validation (in particular use of ground-based network product data TCCON, COCCON, NDACC, PaNIR, AirCore, …)
for CO2M (***operational*** monitoring of ***anthropogenic*** emissisons)

- ***Operational provision of network data (timeliness and availability!)***
- ***Co-located ground-based total column measurements of XCO2, XCH4, NO2 and aerosol close to the sources (complemented by background)***
- ***Contributing requirement to central processing facility of ground based network data for CO2M***

CO2M product Cal/Val

Product Cal/Val and continuous product quality monitoring:

Level-1 calibration:

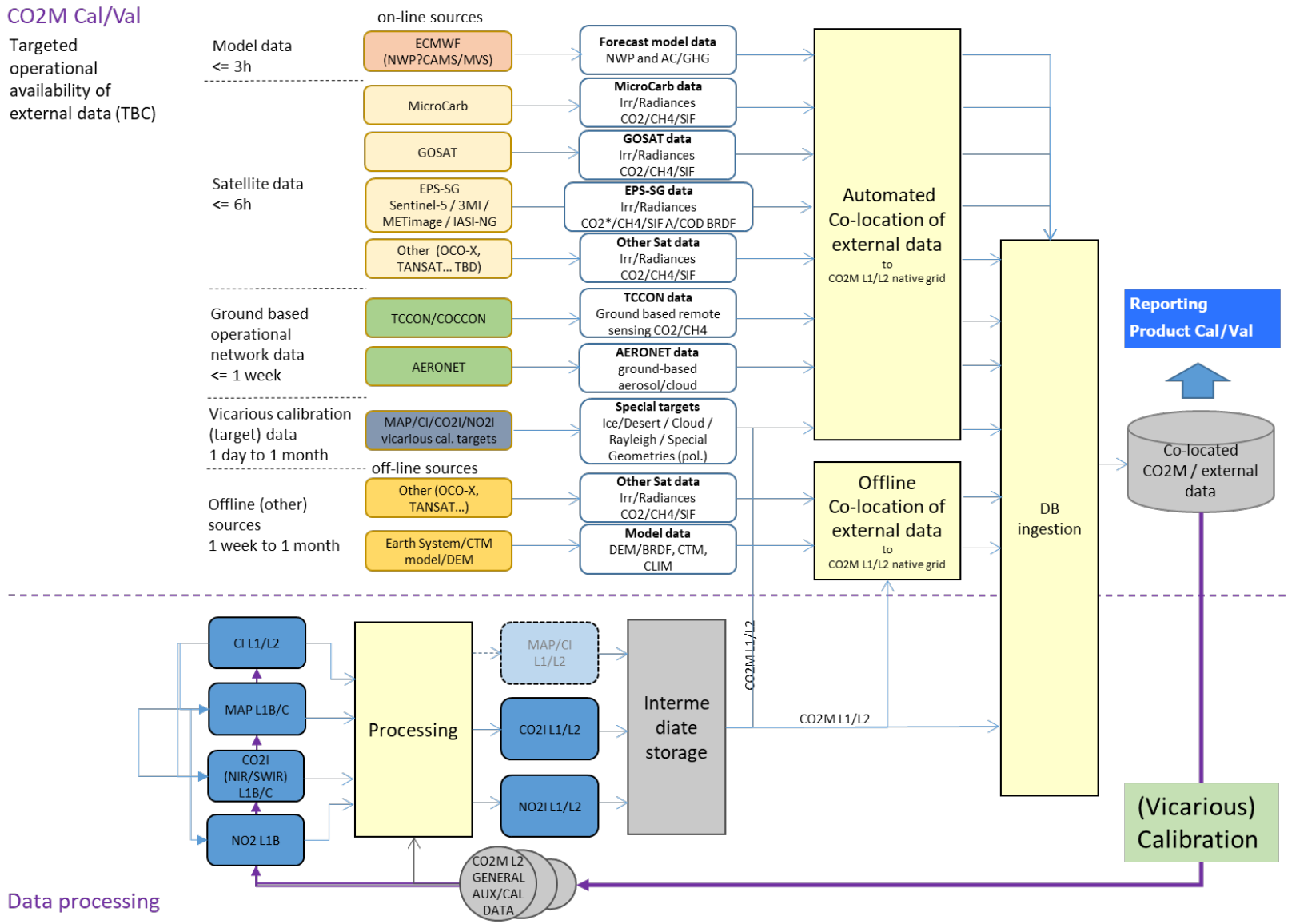
- ✓ Other satellite data (Microcarb, Sentinel-4/5, GOSAT/OCO/Tansat *follow-ons*)

via international partner collaboration, partner agencies, GSICS, WG-Climate, CEOS AC/VC.

- ✓ Solar, on-board and vicarious calibration targets

Level-2 GHG/NO2 (and ancillary) product validation and verification:

- ✓ TCCON / COCCON / PaNIR / NDACC
- ✓ Other ground-based (MAX-DOAS, Aeronet, etc.)
- ✓ Model data (CO2 MVS, NWP, CTM and Earth system)



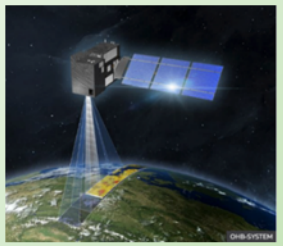
"Four+-pillar" CO2M validation

GSICS

On-board Cal:

Source	CO2I	MAP	CLIM	Frequency
SUN	X	X		daily
Moon	X	X	X	Irreg.
WLS	X			weekly
Tuneable LED	X (ISRF)			
Dark	X	X	X	orbit

Vicarious Cal
"as needed"



CO2M
0.3 nm (@1.6 µm)

- SNOs
- Ref. Targets
- etc.

Cross-Cal

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

~0.05 nm (@1.6 µm)

GSICS

Product VAL

Product Cal/Val

Product Cal/Val

Product Cal/Val

PANDONIA
5 nm (@1.6 µm)

Cross-Cal

COCCON
0.14 nm (@1.6 µm)

Cross-Cal

TCCON / NDACC-FTIR
0.001 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

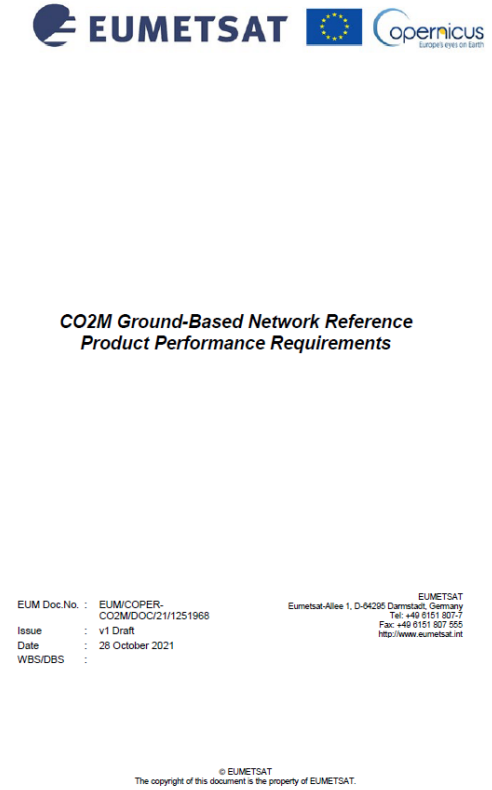
+ NDACC/Aeronet for NO2 and AOD

Ground-based network product requirements for CO2M

EUMETSAT is working on ground-based network product requirements for future operational CO2M product validation

Document scope:

- Requirements for ground-based network (COCCON, TCCON, NDACC, PaNIR, Aeronet, etc..) product performance: ***Co-located*** total column XCO2, XCH4, NO2, and AOD measurements
- Availability and timeliness requirements
- Traceability of product performance (to WMO or FRM network standard). Inter-station and seasonal biases.


CO2M Ground-Based Network Reference Product Performance Requirements

EUM Doc.No. : EUM/COPER-CO2M/DOC/21/1251968
Issue : v1 Draft
Date : 26 October 2021
WBS/DBS :

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Input:

- Expected overpass statistics per station for the CO2M constellation
- Station footprint (based on footprint model data)
- Station environmental parameters (surface albedo, terrain height, etc.)
- Collocation criteria

EUM Cal/Val Study

Universität Bremen
LMU
iLab
BIRA-IASB

CO2M product vs Ground-based network product requirements (Sec.4)

Product	Precision	Bias	Precision	Bias
	CO2M		Ground-based network (T/G)	
CO2	0.7 ppm	<0.5 ppm	*0.7 / 0.5 ppm *)*	*0.5 / 0.2 ppm *)*
CH4	10 ppb	<5 ppb	*10 / 5 ppb *)*	*5 / 2 ppb *)*
NO2	1.5x10^{15} molec/cm^2	<3.5x10^{15} molec/cm^2	*1.5 / 0.5 x10^{15} molec/cm^2 *)*	*3.5 / 1.5 x10^{15} molec/cm^2 *)*
Aerosols	0.05 AOD, 500 m LH[1)]	<0.05 AOD, 500 m LH[1)]	<0.04 or 10% (whatever is bigger)	< 0.02
	Angstrom Exponent (AE) defined at 440 and 865 nm[3)]		0.3[*)] *)potentially bias with signs to be added (range: 0.1 – 0.2)	
	Single Scattering Albedo (SSA) [3)]		0.03*) *)potentially bias with signs to be added (range: 0.01 – 0.02)	
Clouds[2)]	<1% of FOV			

[1)] Aerosol requirements on AOD only provided as a note in MRD. No requirement in SRD.
[2)] Currently clouds is 5% (threshold), but we aim at <1% (goal)
[3)] AE and SSA not mentioned in MRD and SRD

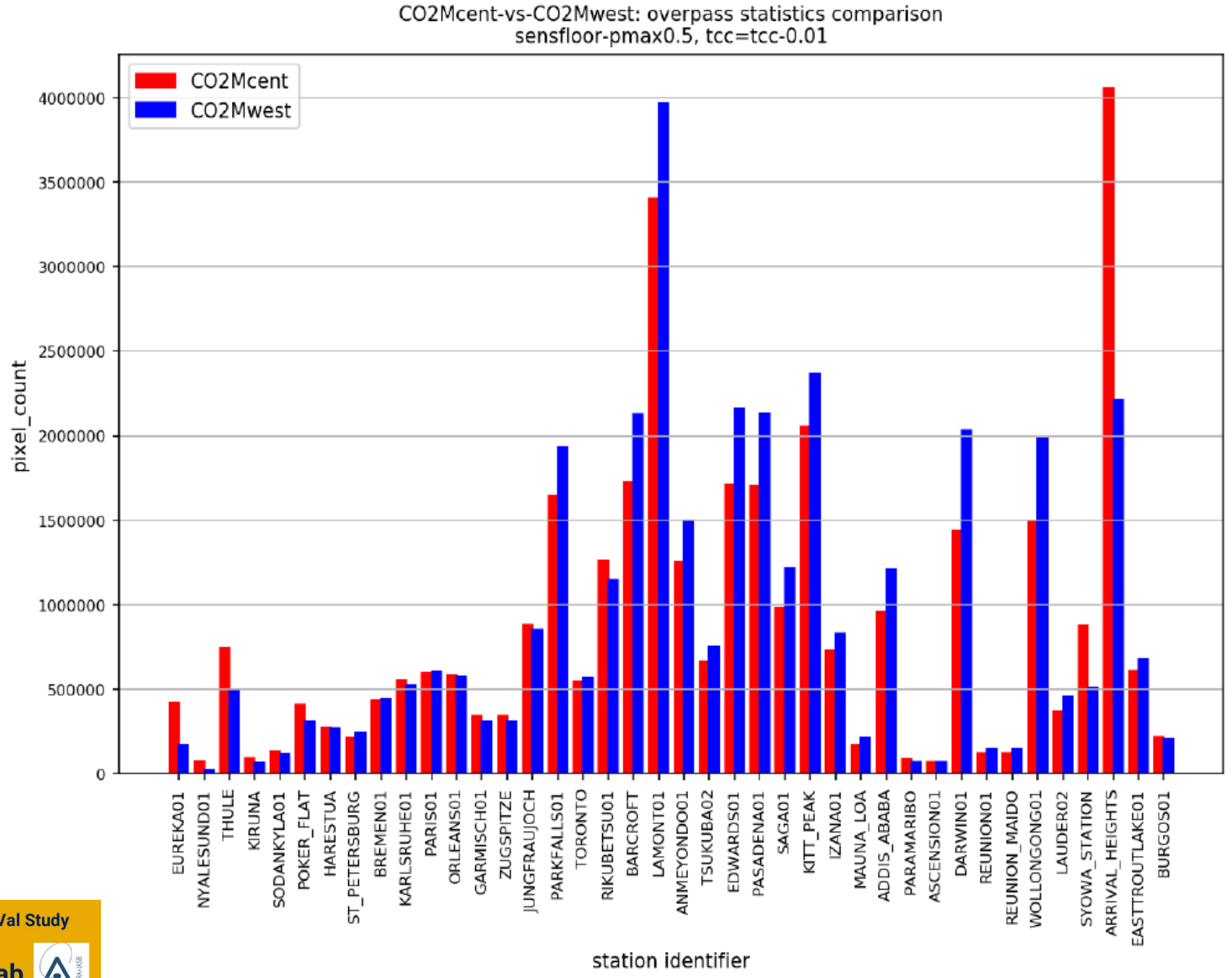
*) -> Values TBD (factor of 2 to 10 better) and to be complemented with station related statistics and variance information!

TCCON / COCCON station overpass statistics

- Analysed sensitivity of XCO2 at observational sites to flux, i.e. **dXCO2/df**
- Footprints indicate a spatial domain over which potential emissions could be observed

+ combining sensitivity with an estimate of actual fossil fuel emissions

➢ Compute for each grid cell **i** the contribution of corresponding emission **fi** to the column



FFDAS station footprint simulation:

Column sensitivity [ppm]

Emission sensitivity [ppm/kgC/m2/day]

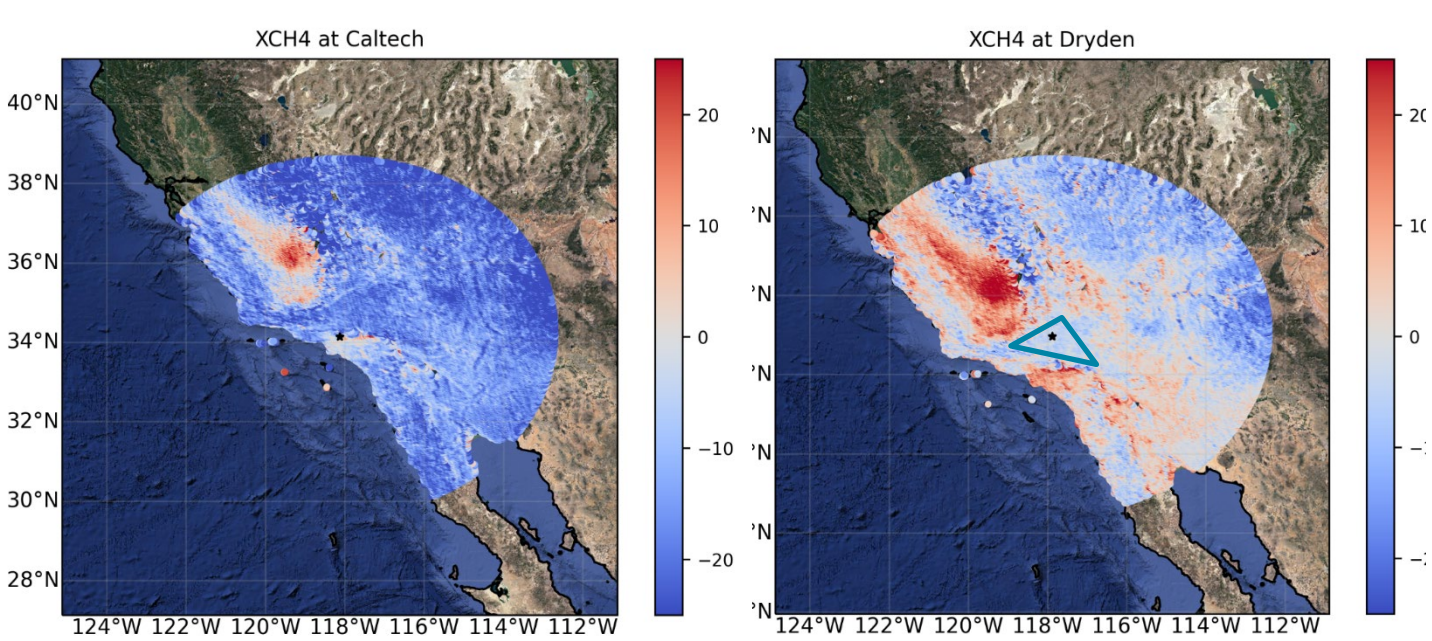
iLab Kaminski et al., EUM CalVal study

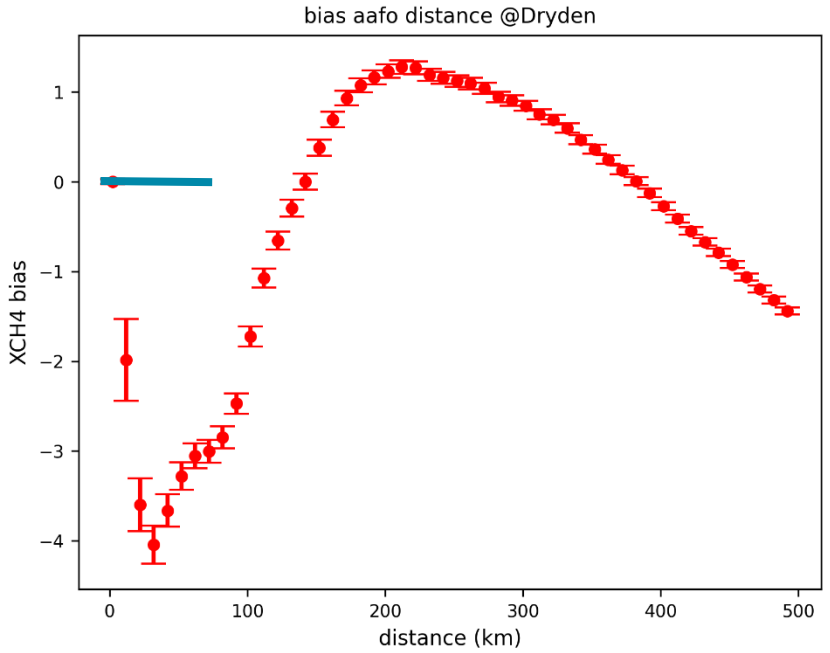
EUM Cal/Val Study

Co-location criteria

Dryden/Edwards XCH4 bias wrt TCCON sites

San Joaquin valley (dairy farms)





Dils et al, BIRA, EUM CalVal study

Over 10 ppb bias >90 km

➢ Evaluate best co-location criteria per stations
+ overpass and footprint statistic

EUM Cal/Val Study

LMU iLab

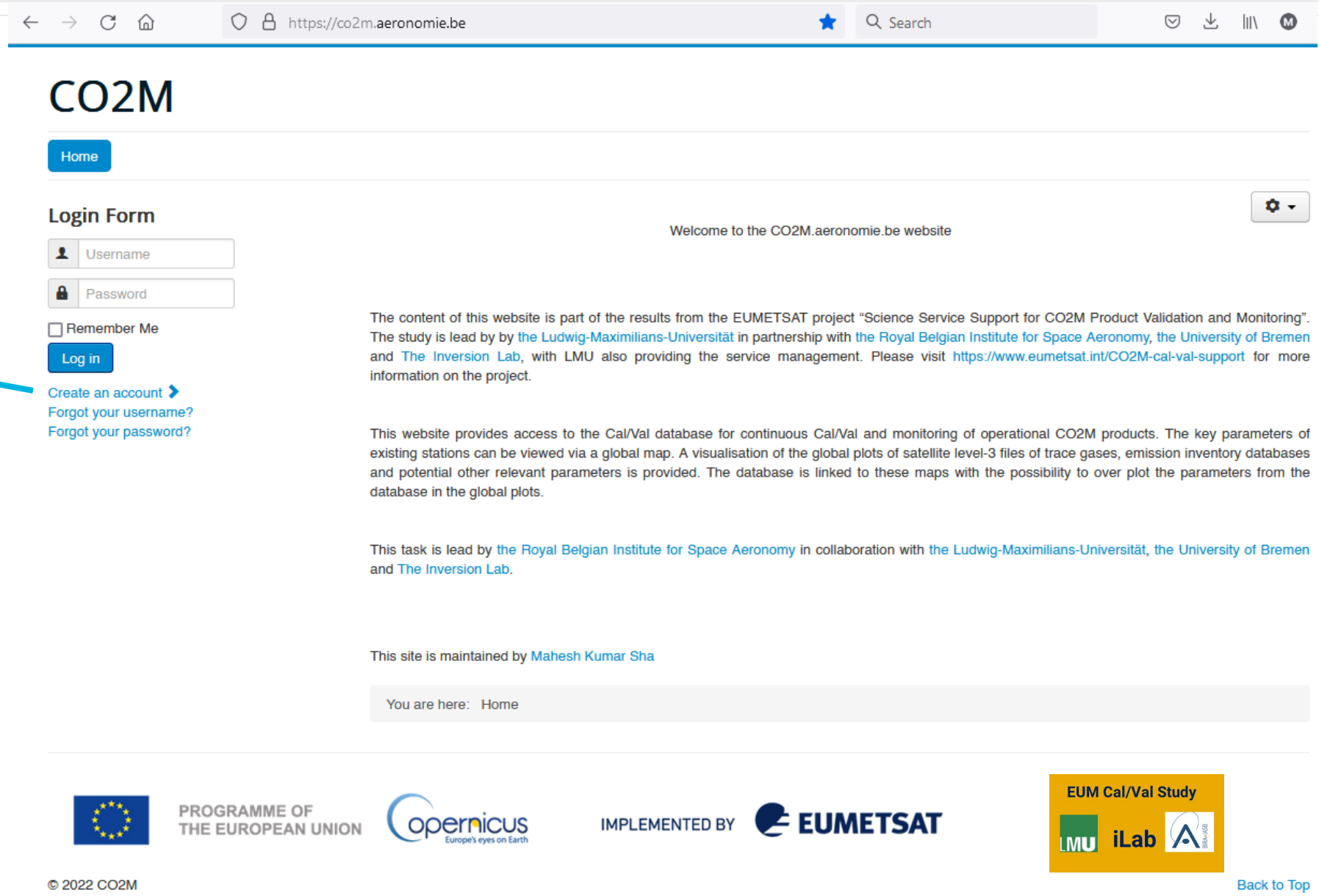
Complement ground-based network product overall goal performance for XCO2/XCH4 with station specific variance expectations

Map server

CO2M project map server:
https://co2m.aeronomie.be/

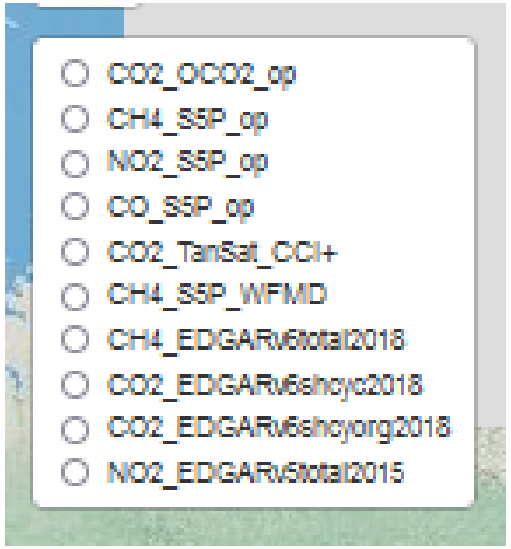
Create an account

Login with your **Username** & **Password** and check “Remember Me” box for future easy login



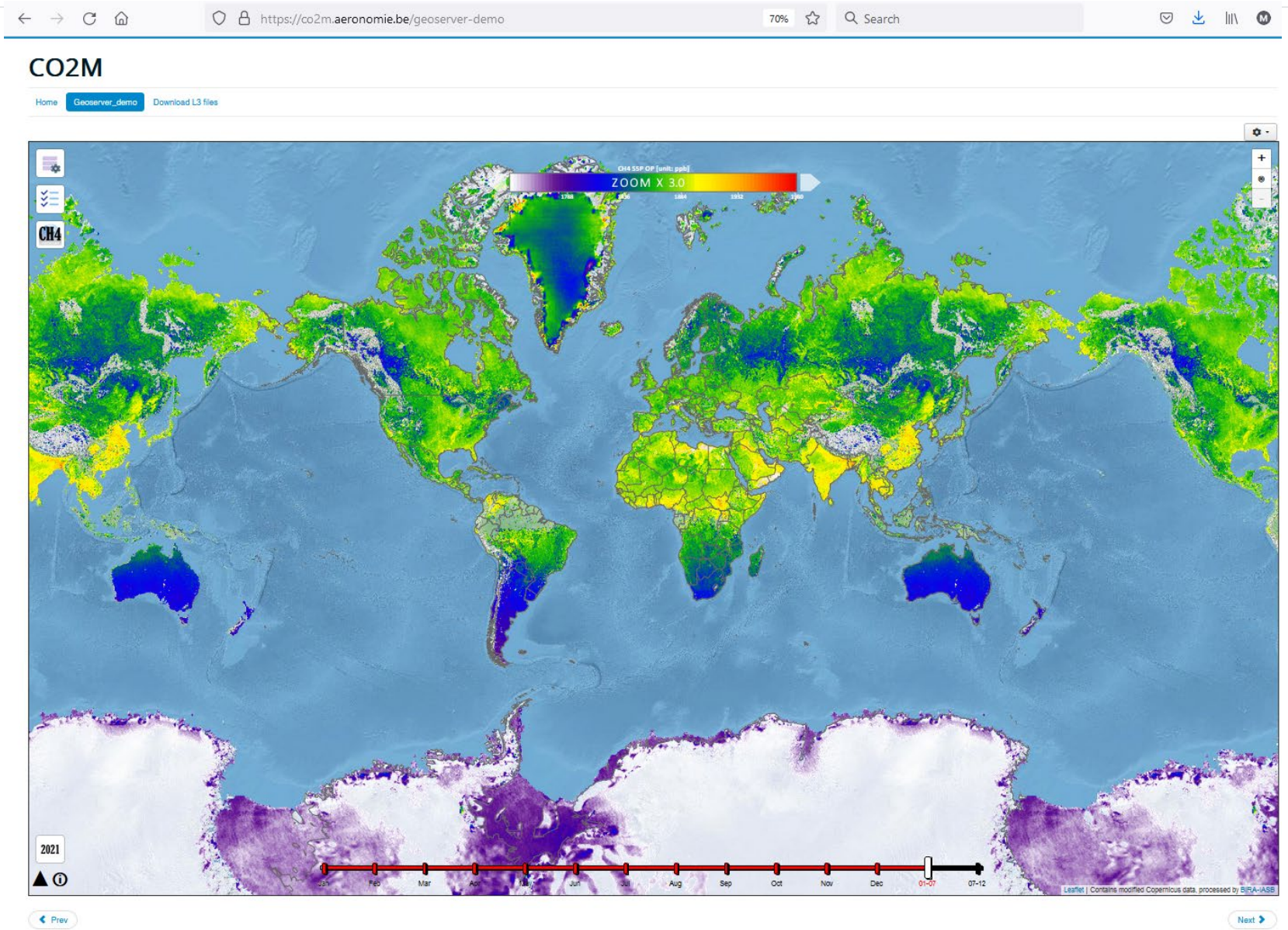
Map server – Satellite & database visualisation

Visualisation of monthly/yearly averaged satellite files



Possibility to view monthly evolution and their comparisons

Handling of data processed with different processor versions



EUM Cal/Val Study

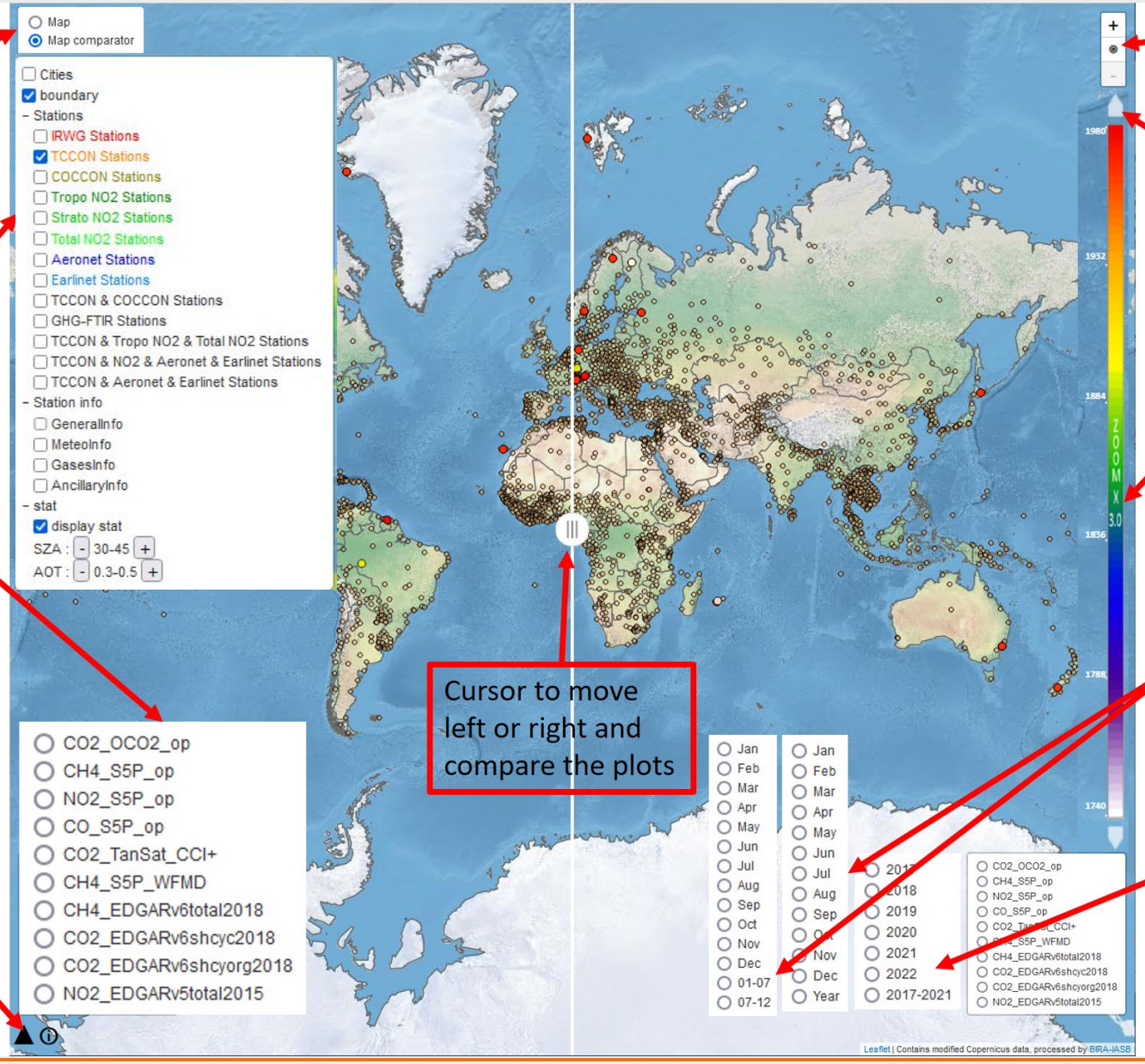
Map server – visualisation options

Select individual maps or comparator view

Select list of stations from database with information on parameters, cities, list of stations based on networks – TCCON, COCCON, NDACC, AERONET, ERLINET, …

Select species for visualisation – SAT L3 files or emission data

Information on the content of the data plotted



Cursor to move left or right and compare the plots

Zooming of the map

Scrolling option for changing range of the colour scale

Multi level zooming option for the optimised range of the colour scale

Select individual month or yearly average or option to view average of different versions of the SAT data

Select individual year or multi-year average

eumetsat.int

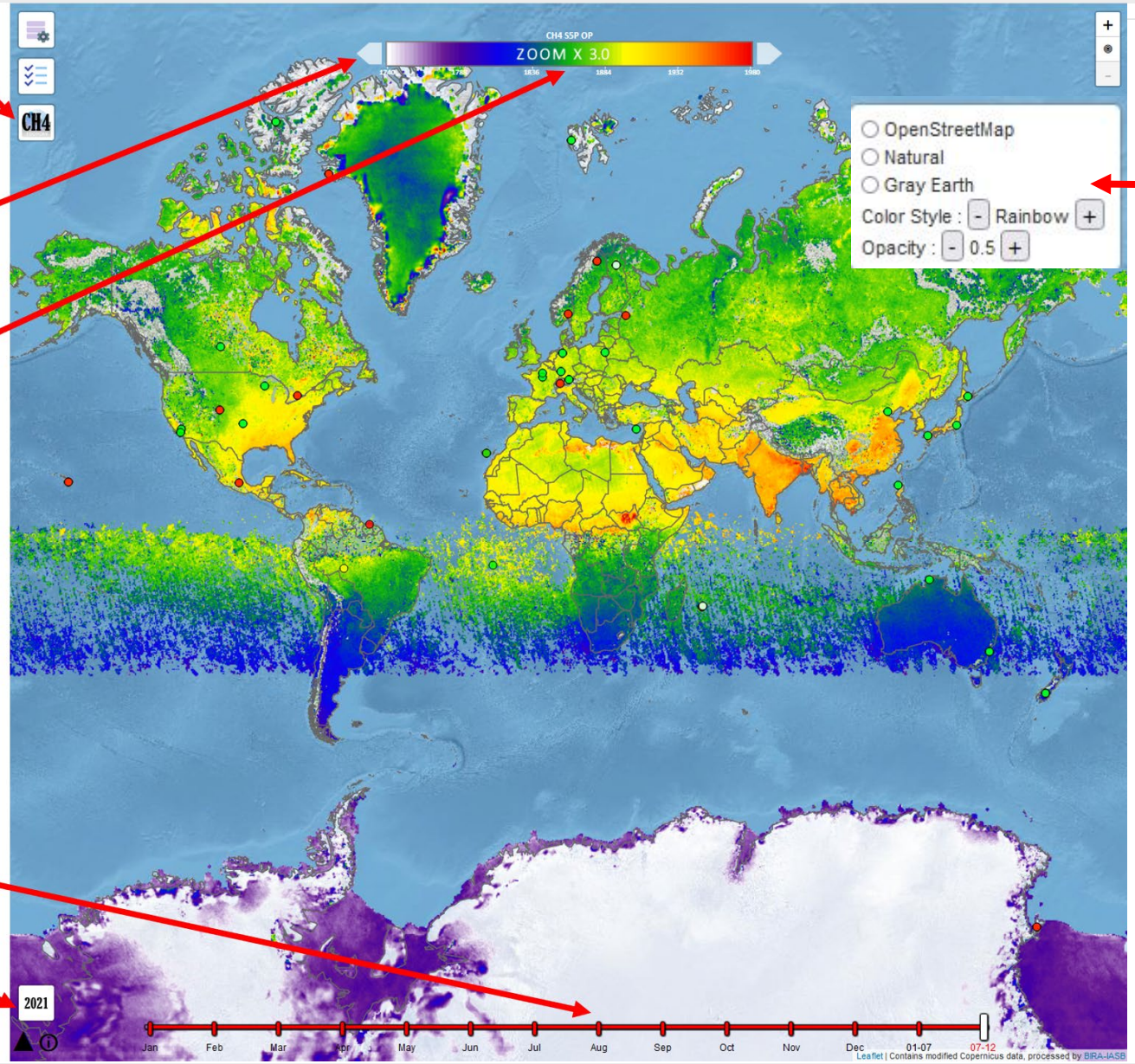
EUM Cal/Val Study

Map server – Satellite & database visualisation

CH4_S5P_OP

Scrolling option for changing range of the colour scale

Zoom option



Options for changing background Earth, color Style and Opacity

Monthly or yearly averages

CH4_S5P_OP

EUM Cal/Val Study

IWGGMS-19 – Workshop on ground-based network status for CO2M

Together with the Cal/Val study and with the support of CNES we are planning to organise a workshop at the forthcoming IWGGMS-19 meeting (4-6 July), Paris

- Workshop title: **“Ground-based network design workshop for validation of CO2M/MicroCarb and related missions”**.
- A draft web-page exists for participants to register under https://events.spacepole.be/event/167/
- Location: CNES headquarters, Paris
- Time: 7th July 2023, 10:00 – 16:00 CEST

Appendix

Solar reference

Performance parameter: Absolute radiometric accuracy of the solar port
Performance target: Signal accuracy and stability / throughput (diffuser) and detector degradation

Resource: Solar reference spectra (high spectral resolution <0.01 nm from 250 to 2500 nm)
Needs: GSICS validation and recommendation
Research target: UV to SWIR

Target
GSICS UVNS contribution: methods, procedures, resources

Lunar reference

Performance parameter: Absolute radiometric accuracy of the earthshine port
Performance target: Signal accuracy and stability / throughput (diffuser) and detector degradation

Resource: Lunar (polarised) surface reflectance model (high spectral resolution <0.1 nm from 250 to 2500 nm)
Needs: GSICS lunar geometric (phase) and radiometric model (ROLO) / validation and recommendation
Research target: UV to SWIR / polarisation of lunar signal / lunar disk phase model / lunar high spatial resolution surface albedo

Target
GSICS UVNS contribution: methods, procedures, resources

SNOs

Performance parameter: Absolute radiometric accuracy of the earthshine port
Performance target: Signal absolute and relative accuracy and stability / mission inter-calibration / ISRF monitoring (imager vs spectrometer)

Resource: Simultaneous Nadir Overpass (SNO) database (multi-mission) LEO-LEO / LEO-GEO / GEO-GEO; cross—calibration coefficients
Needs: SNO database maintenance (long-term)
Research target: Expansion of database to provision of derived co-located spectra / images

Target
GSICS UVNS contribution: methods, procedures, resources