Copernicus CO2M Mission – continuous operations, product processing and Cal/Val

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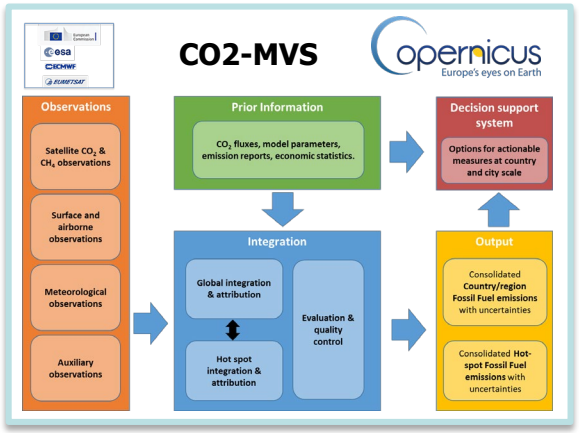


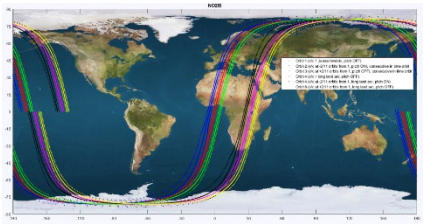
CO2M Products requirements:

Product	Spatial resolution	Precision
CO2	4 km²	0.7 ppm
CH4	4 km²	10 ppb (est.)
NO2	4 km²	1.5×10^{15} molec/cm²
SIF*	4 km²	0.7 mW m^{-2} sr^{-1} nm^{-1}
Aerosols	16 km²	0.05 AOD, 500 m LH
Clouds	<5% of FOV	Water & cirrus clouds

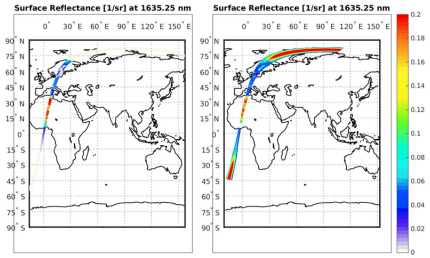
VIS band also covers CHOCHO (glyoxal)
VIS & SWIR band also covers water vapour
*Top-of-Atmosphere Solar Induced Fluorescence

Estimated amount of data (per orbit, per satellite):

Number of measurements:
~1.1 million
Level-1 product size (CO2-IS /NO2-IS):
~25 / 12 Gb
Number of clear sky retrievals:
~200.000
Level-2 product size (GHG / NO2):
~2 / 1 Gb
Product availability/timeliness
>95% / 24 h



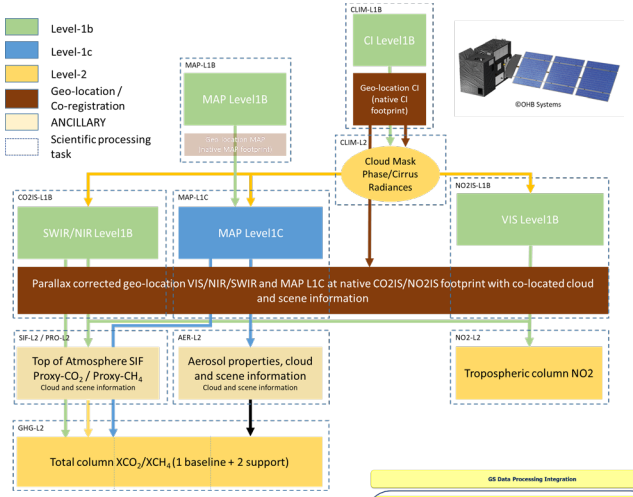
Three platforms operated in tandem to maximise coverage north of 40°



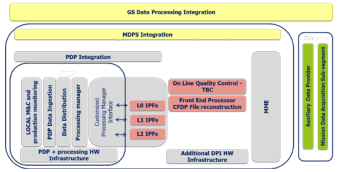
Agile platforms can be operated following the glint spot (increasing water-body surface reflectance)

NO2-IS: Grating spectrometer operating in the visible
CO2-IS: Grating spectrometer operating in the NIR and SWIR
MAP: Multi-Angle Polarimeter (41 views) operating in 6 VIS bands
CLIM: Cloud-imager operated at <400 m resolution at 670 and 1320 nm

CO2M Product Processing and Interdependencies:



EUMETSAT CO2M Payload Data Processing (PDP):



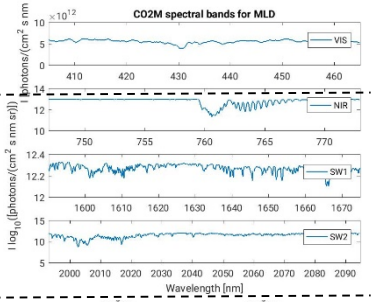
Correspondence: Ruediger Lang, ruediger.lang@eumetsat.int

Level-1b NO2-IS:

Calibrated radiances
VIS (405 – 490 nm)

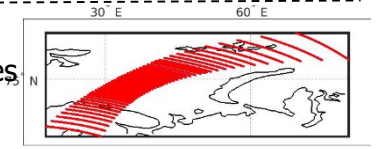
Level-1b CO2-IS:

Calibrated radiances
NIR (747 – 773 nm)
SWIR-1 (1590 -1675)
SWIR-2 (1990 -2095)



Level-1b MAP:

Calibrated pol. radiances
(410 443 490 555 670 753 865 nm)

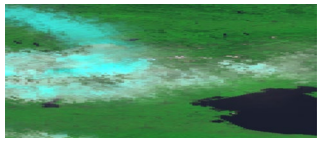


Level-1c MAP:

Multi-view I,Q,U radiances at **CO2-IS** footprint

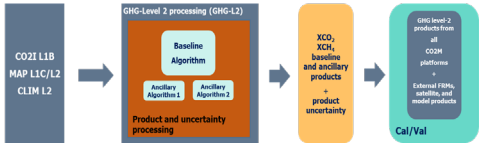
Level-1b CLIM:

Calibrated radiances
(670 753 1320 nm)

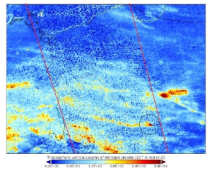


Cloud and cirrus flag / cloud and cirrus obstruction at native resolution

CO2M GHG level-2 product: XCO2 / XCH4

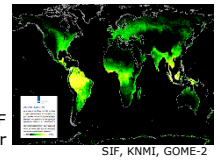


CO2M NO2 level-2 product (plume mapping)



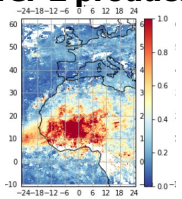
NO2, KNMI, S5p

CO2M SIF/Aerosol level-2 product



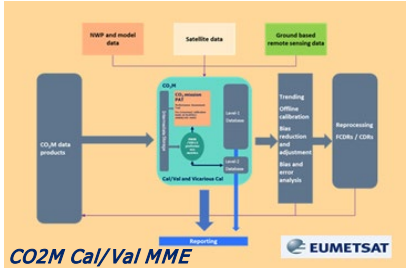
SIF
U. Leicester

SIF, KNMI, GOME-2



AOD, GRASP, POLDER

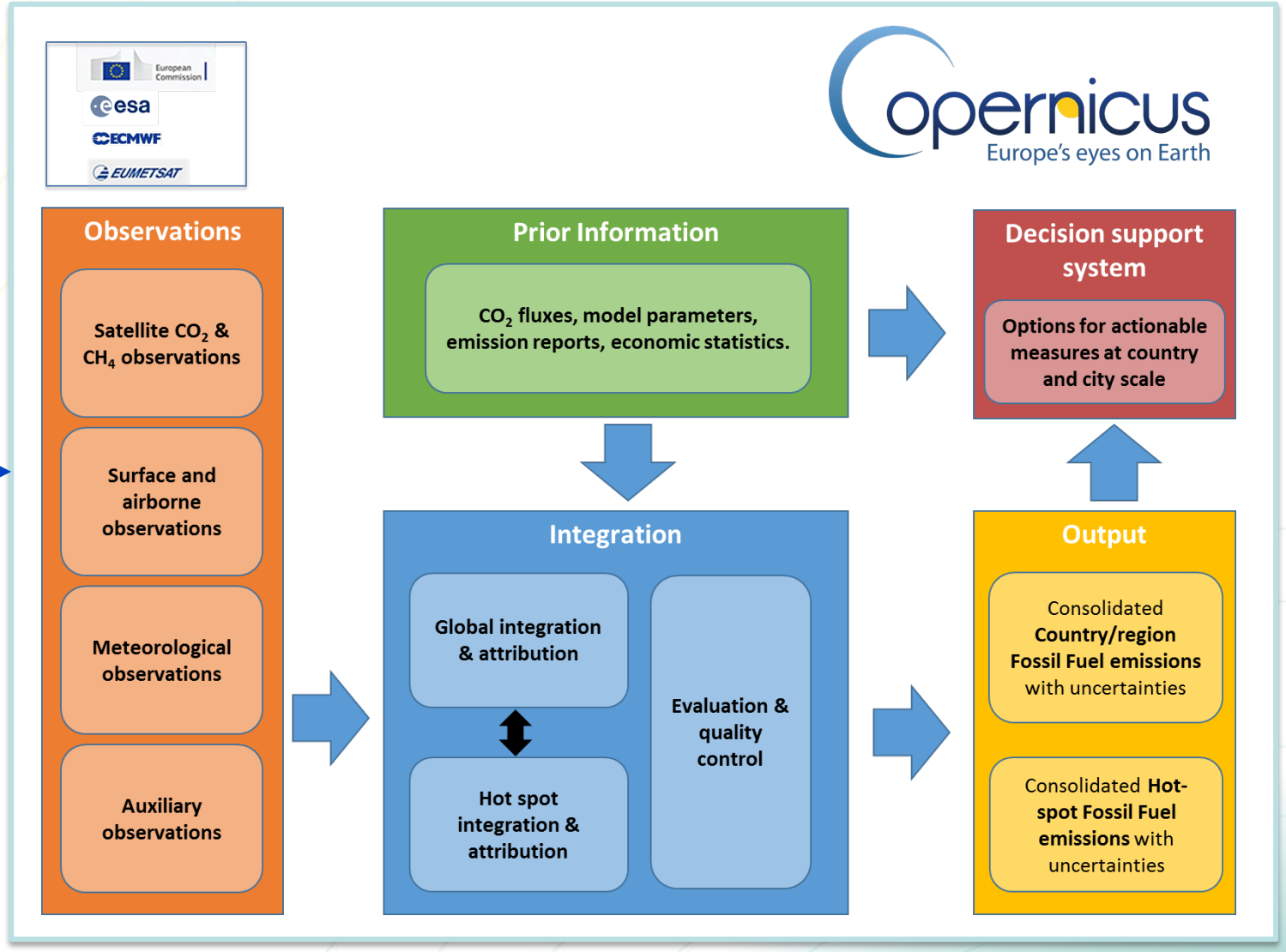
CO2M mission products for the Copernicus CO2 Monitoring and Verification Support Capacity



CO2M Cal/Val MME

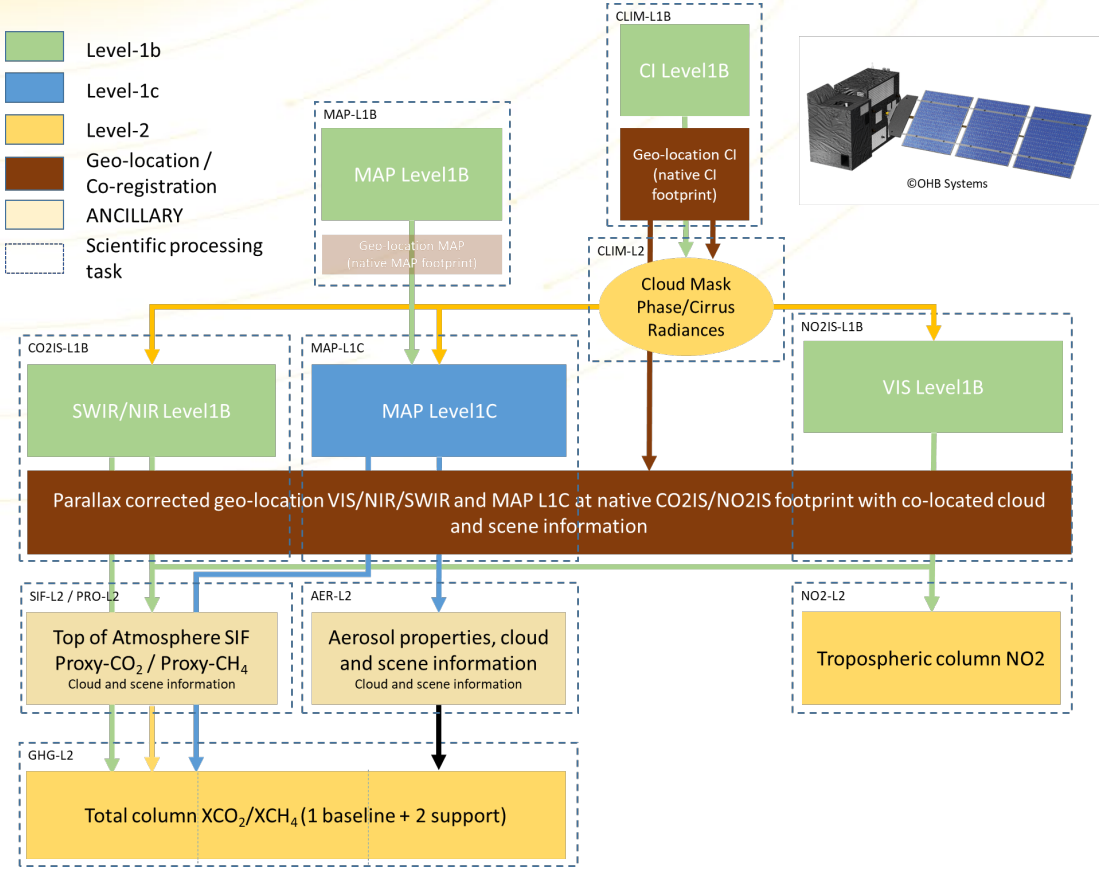
CO2M Cal/Val external sources:

- Other mission data
- Ground-based FRM data
- Model (analysis/forecast) data



Copernicus CO2M mission – processing and products

CO2M Product Processing and Interdependencies:



Functional processing flow in
EUMETSAT CO2M Payload Data Processing (PDP)

CO2M Products requirements (MRD v3):

Product	Spatial resolution	Precision
CO2	4 km^2	0.7 ppm
CH4	4 km^2	10 ppb (est.)
NO2	4 km^2	1.5×10^{15} molec/cm^2
SIF*	4 km^2	0.7 mW m^{-2} sr^{-1} nm^{-1}
Aerosols	16 km^2	0.05 AOD, 500 m LH
Clouds	<5% of FOV	Water & cirrus clouds

VIS band also covers CHOCHO (glyoxal)
VIS & SWIR band also covers water vapour
*Top-of-Atmosphere Solar Induced Fluorescence

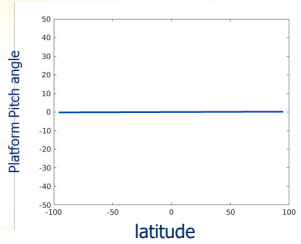
Estimated amount of data (per orbit, per satellite):

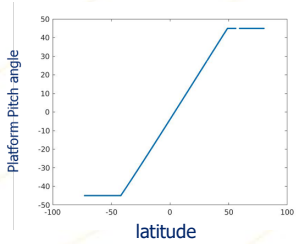
Number of measurements:	~1.1 million
Number of clear sky retrievals:	~200.000
Level-1 product size:	~20 Gb
Level-2 product size:	~5 Gb

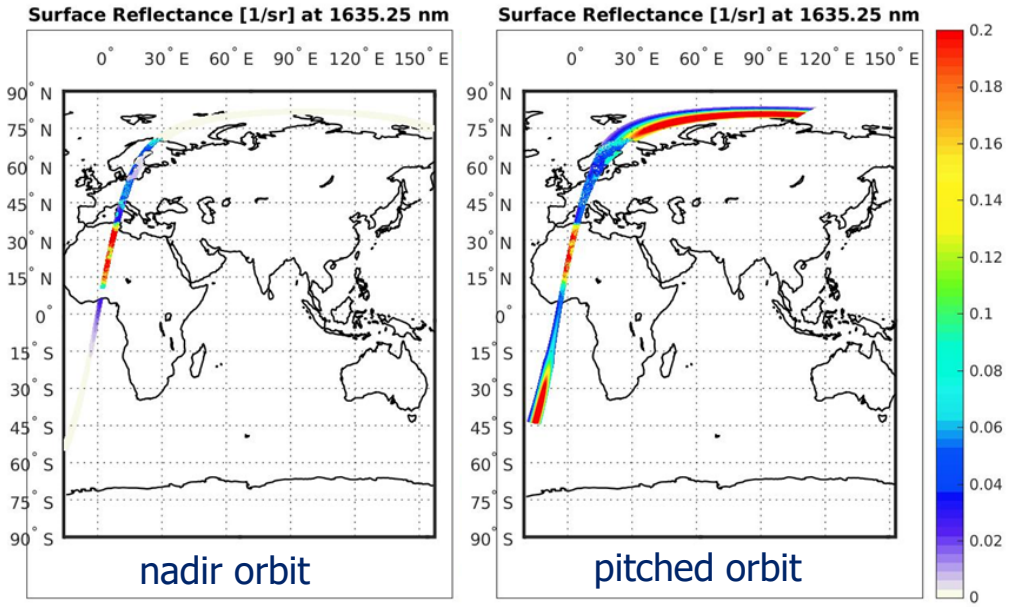
CO2M orbit and geo-location products for XCO2/XCH4

Glint-spot platform pointing:

Platform pitch angle profile (model scenarios TBC):

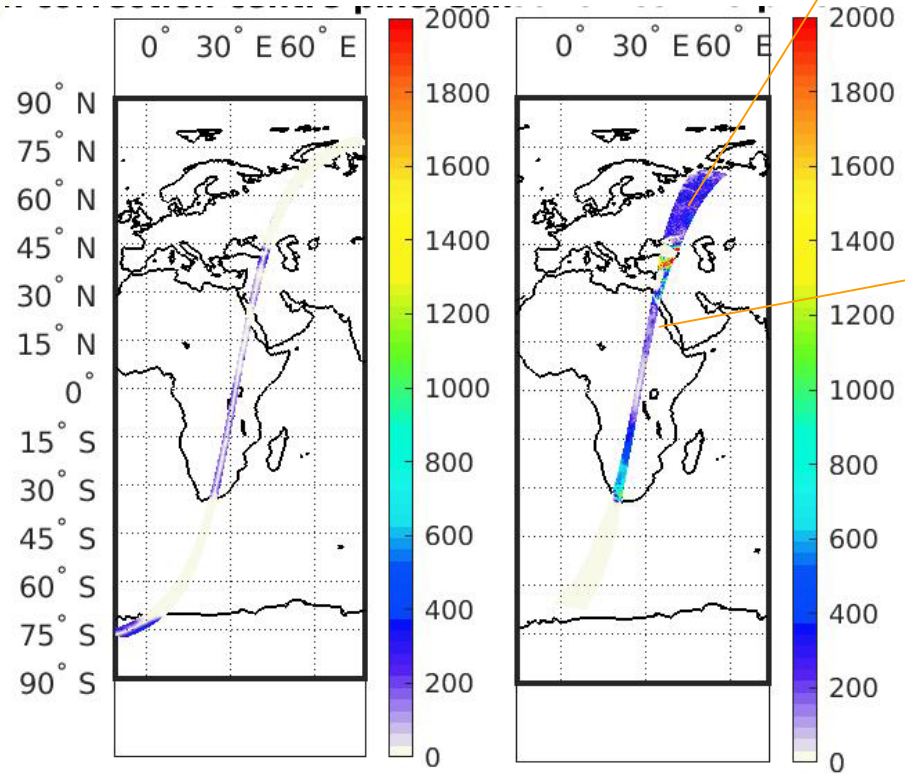




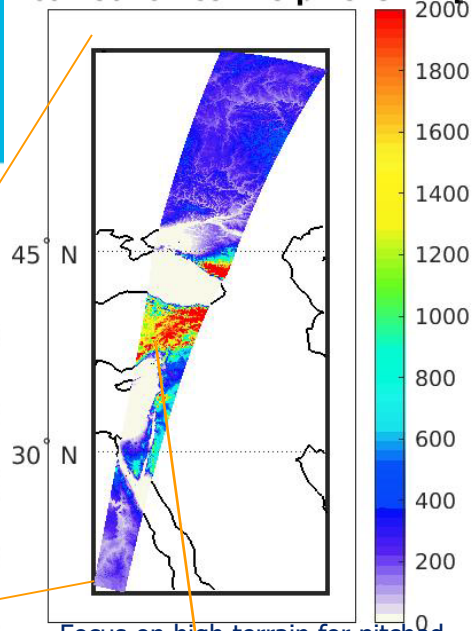


Geo-location product, parallax correction:

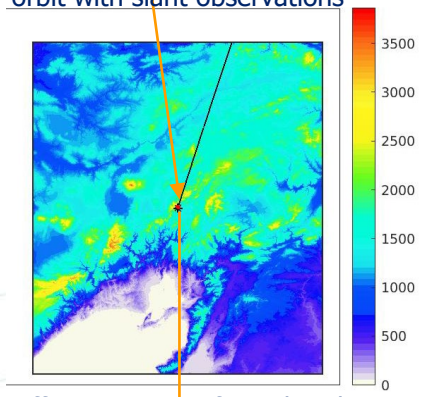
Parallax correction for CO2-IS/NO2-IS level-1b [m]:



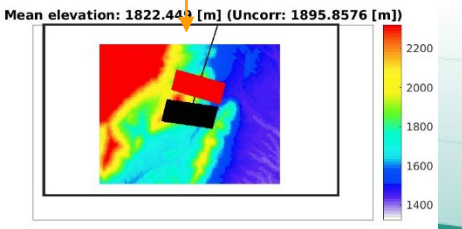
Use of Copernicus 9" DEM



Focus on high terrain for pitched orbit with slant observations



Affects mean surface altitude as well as geo-location



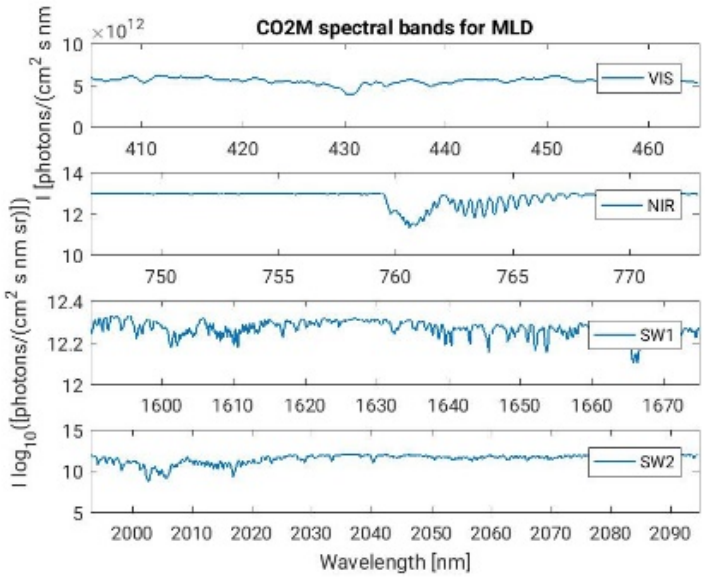
Even more important for MAP L1C product

Top-Of-Atmosphere simulations for Copernicus CO2M
https://www.eumetsat.int/CO2M-TOA-TDS

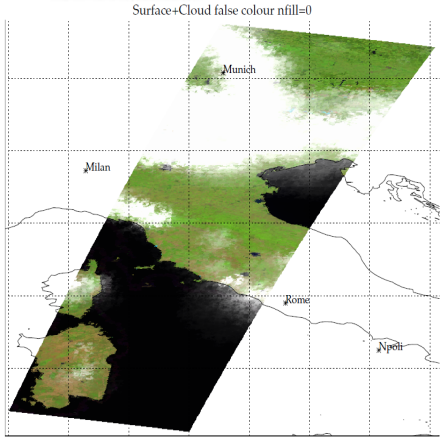
Copernicus CO2M mission – level-1 radiance and cloud products

Level-1b NO2-IS:
Calibrated radiances
VIS (405 – 490 nm)

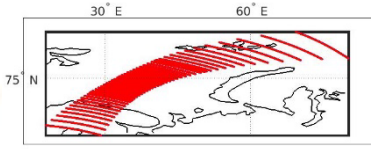
Level-1b CO2-IS:
Calibrated radiances
NIR (747 – 773 nm)
SWIR-1 (1590 -1675 nm)
SWIR-2 (1990 -2095 nm)



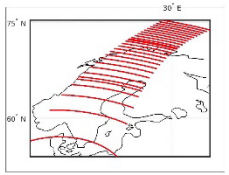
False-color image VIS/NIR/SWIR-1 for modelled CO2M radiances from prelim. EUM test-data-set *(From EUM test-data study)*



Level-1b MAP:
Calibrated pol. radiances
(410 443 490 555 670 (753) 865 nm)

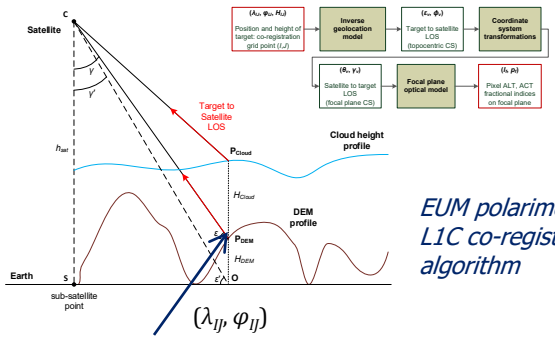


MAP footprint nadir orbit



MAP footprint pitched glint orbit

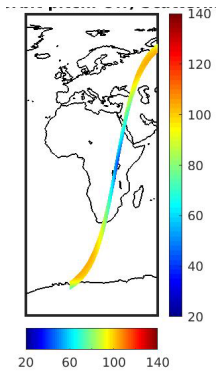
Level-1c MAP:
Multi-view I,Q,U radiances at **CO2-IS** footprint



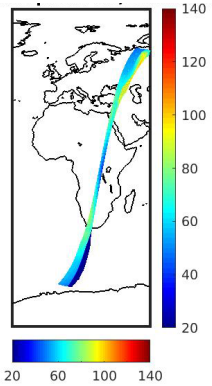
EUM polarimeter L1C co-registration algorithm

$(\lambda_{IJ}, \varphi_{IJ})$

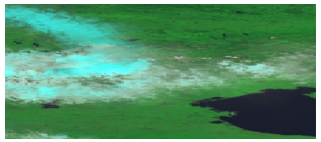
Pointing from *P* at CO2-IS lat/lon footprint point *(λ,φ),* from terrain height *H* to MAP instrument detector plane. (Cloud height parallax not considered for CO2M, TBC)



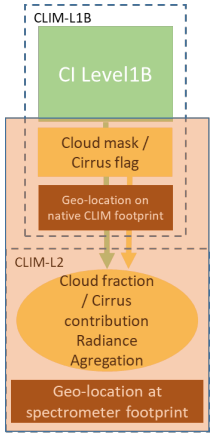
Scattering angle range of MAP-L1C product for a nominal (left) and a glint-pointing, pitched orbit (right)



Level-1b CLIM:
Calibrated radiances
(670 753 1320 nm)



Cloud and cirrus flag /
cloud and cirrus obstruction at native resolution



EUM cloud CLIM L2 study (Syn-Cloud): Brockmann Consult

Level-2 CLIM:
Aggregated cloud and cirrus obstruction at CO2-IS resolution:

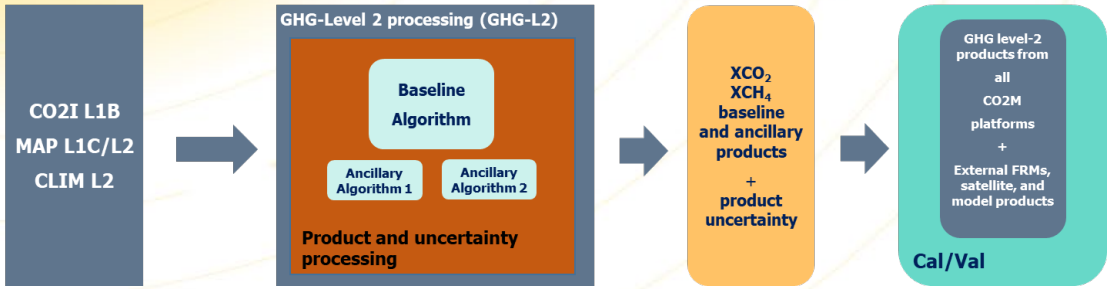
- Cloud fraction (geometric)
- Cloud top height (TBD)
- Cloud obstruction (radiometric)
- Scene inhomogeneity (std of imager radiances)

Additional cloud information:

- *CO2-IS NIR:* Oxygen A-Band
- *NO2-IS:* $(O_2)_2$ absorption
- *MAP*: I, Q, U (Rainbow, cloud type, …)
- CO2-IS SWIR: cirrus

Copernicus CO2M mission – level-2 products

CO2M GHG level-2 product: XCO2 / XCH4

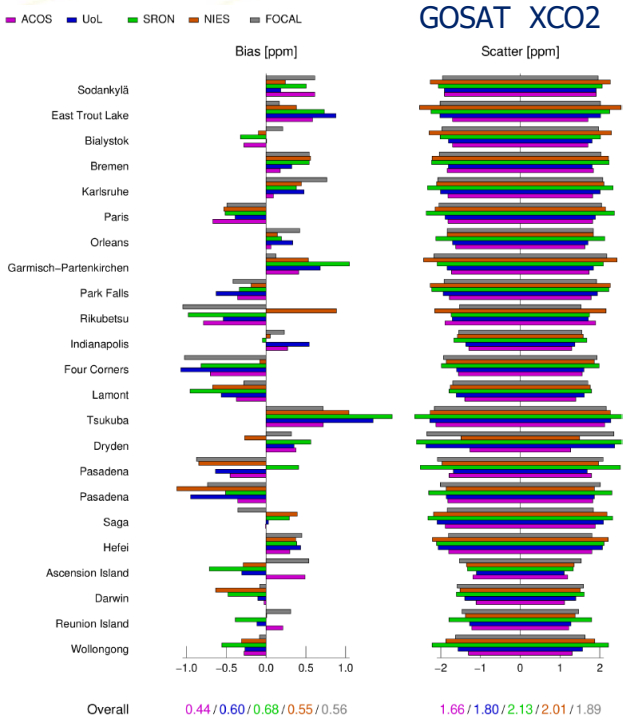


EUM GHG level-2 study algorithms:

RemoTAP (SRON)
FOCAL (U. Bremen)
UoL-FP (U. Leicester)

CO2M Products requirements:

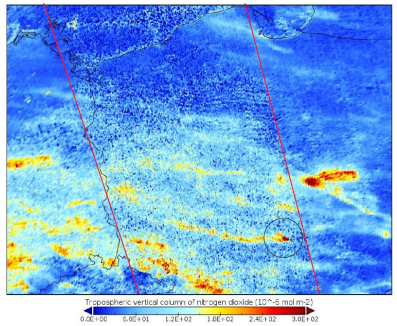
Product	Spatial resolution	Precision
CO2	4 km²	0.7 ppm
CH4	4 km²	10 ppb (est.)
NO2	4 km²	1.5x10¹⁵ molec/cm²
SIF*	4 km²	0.7 mW m⁻² sr⁻¹ nm⁻¹
Aerosols	16 km²	0.05 AOD, 500 m LH
Clouds	<5% of FOV	Water & cirrus clouds



Noel et al., AMT 2021

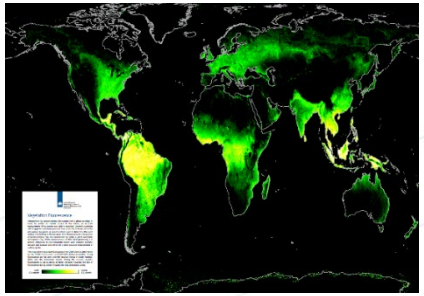
CO2M NO2 level-2 product (plume mapping)

EUM NO2 level-2 study algorithm: TriOpSys/KNMI

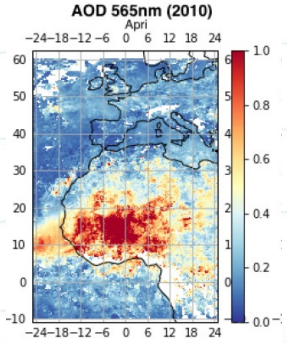


TropOMI/S5p zoom mode at ~2x2 km

CO2M SIF and Aerosol level-2 product



EUM SIF level-2 study algorithm: U. Leicester



EUM Aerosol level-2 study algorithms: GRASP (GRASP-SAS/U. Lille)