Copernicus Anthropogenic CO_2 Monitoring (CO2M) Mission
---- AQ & GHG aspects ----

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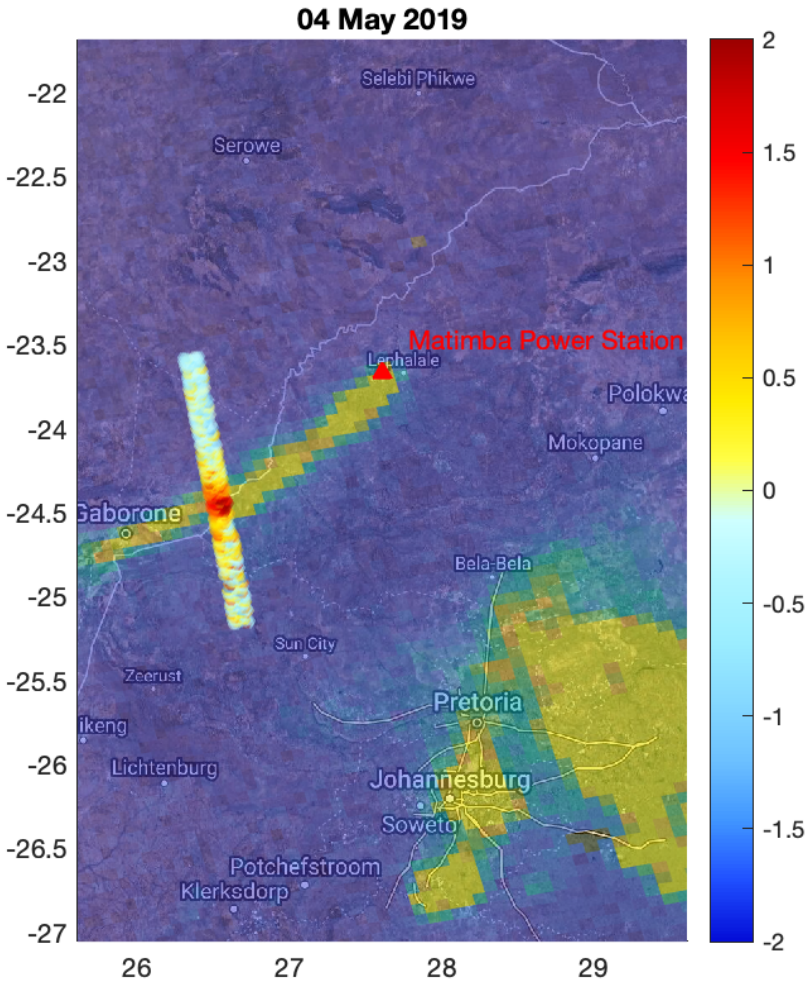
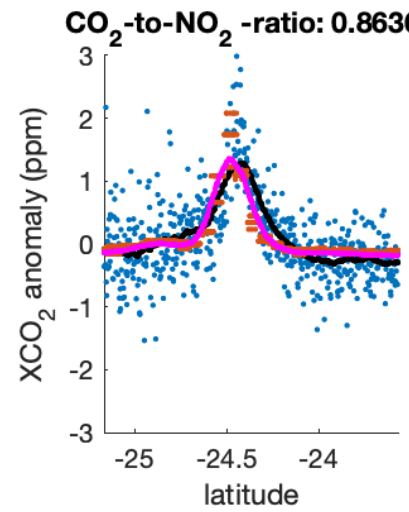
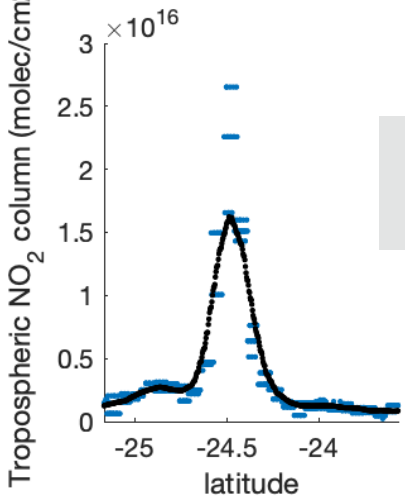
& CO_2M Mission Advisory Group

Matimba power station (S-Africa)

Data:
XCO_2 from OCO-2
and NO_2 from
Sentinel-5 Precursor







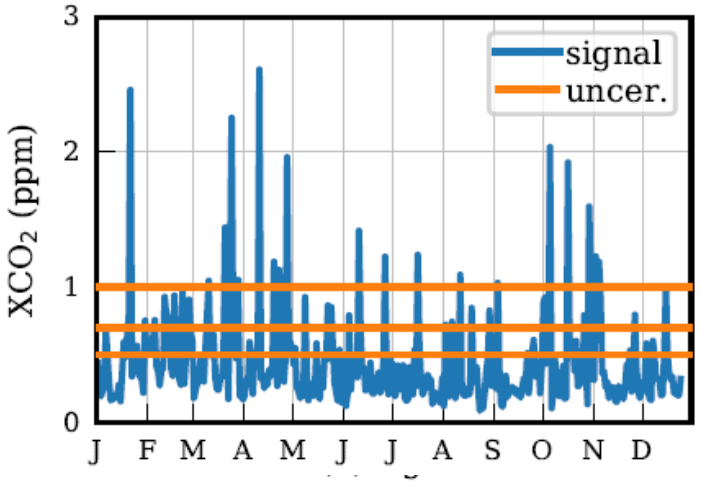
Credits:
ESA's DACES study, FMI

Plume detection: noise & background variability

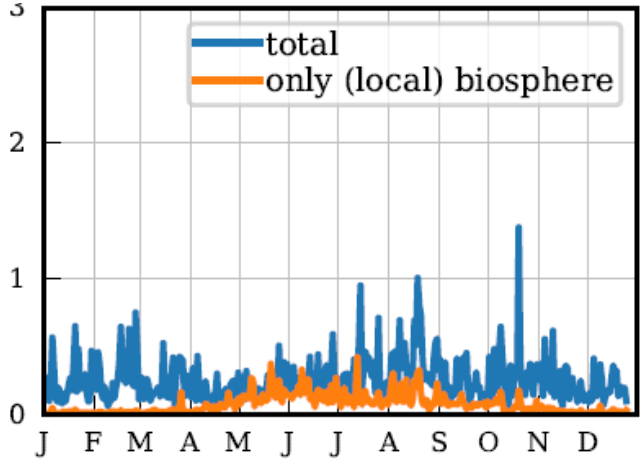
Berlin plume peak signal

Spatial variability of background

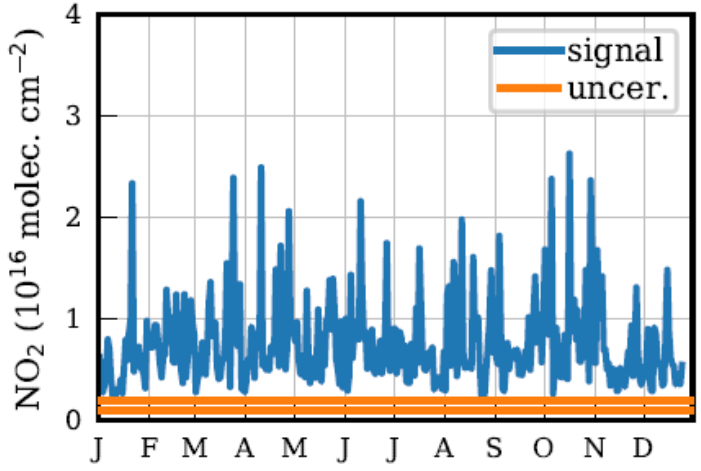
CO_2

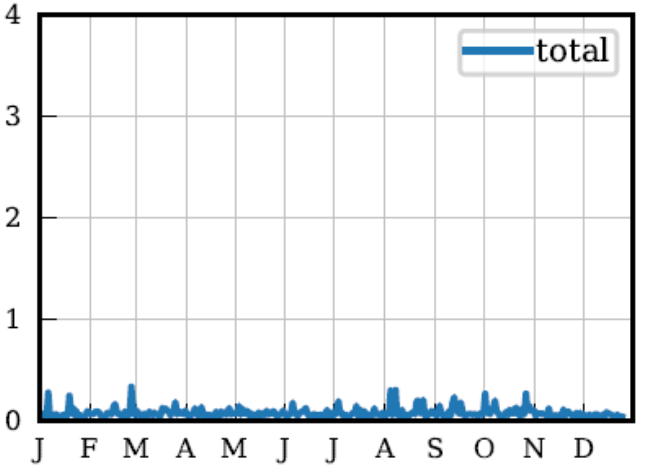


High noise
Medium noise
Low noise



NO_2





Credits: ESA's SMARTCARB study, Empa

Detection capability: CO_2 vs NO_2

Instrument (uncertainty)	Number of plumes (percentage of all plumes)		Plume sizes (true positives)
	>0 pixels	>100 pixels	Mean number of pixels
Real CO_2 plumes	53 (100%)	53 (100%)	628
CO_2 (0.7 ppm)	23 (43%)	9 (16%)	107
NO_2 (low noise)	48 (91%)	36 (67%)	271
NO_2 (high noise)	51 (96%)	38 (71%)	261
NO_2 Sentinel-5	29 (55%)	21 (39%)	156

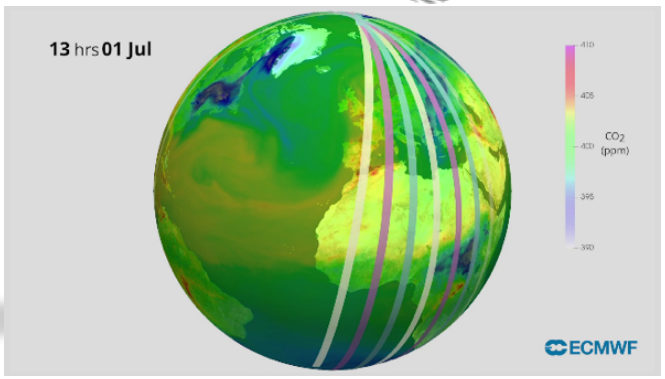
- NO_2 instrument: greatly enhances plume detection rate
- NO_2 instrument: greatly reduces emission bias
- Temporal collocation required (i.e. NO_2 of Sentinel-5 (39%) is less successful
- CO is a different story and not convincing for (collocated) plumes

Credits:
ESA's SMARTCARB study, Empa

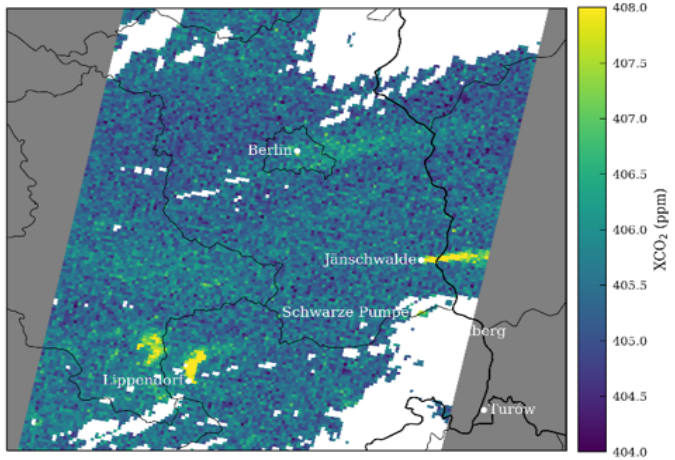
CO2M requirements – XCO_2 & NO_2

Mission requirements for XCO_2 & NO_2:

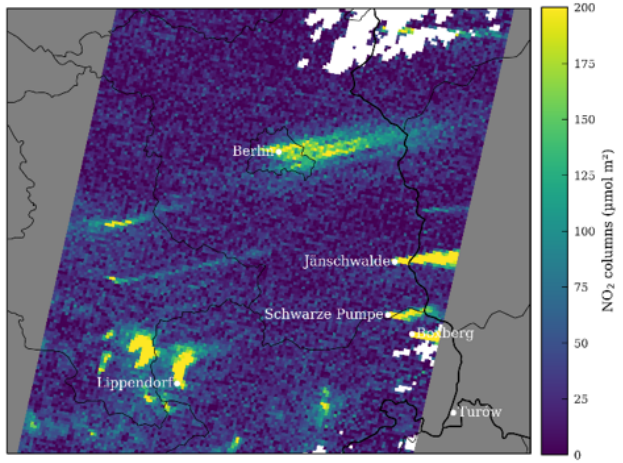
- Spatial resolution **4 km²**
- XCO_2 precision: **0.7 ppm (veg. scene, 50° SZA)**
- NO_2 precision: **1.5·10¹⁵ molec/cm²**
- Imaging swath **> 250 km**
- Est. XCH_4 precision: **~10 ppb (veg. scene, 50° SZA)**



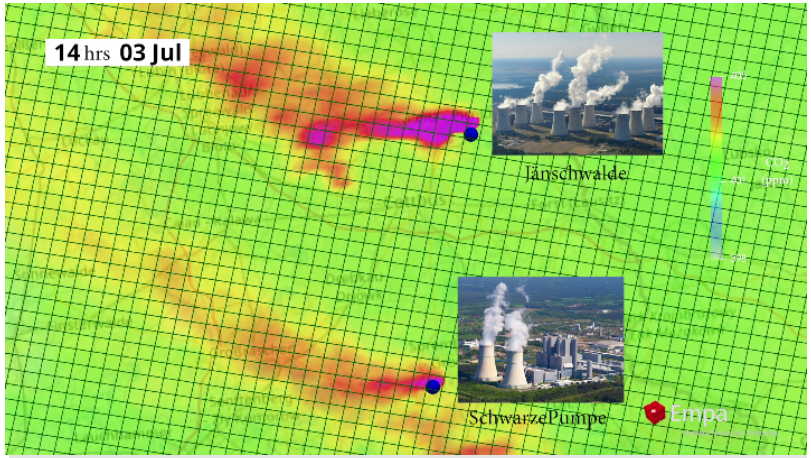
Simulated XCO_2 plumes



Simulated NO_2 plumes



CO_2 measured at 2x2 km² grid



Credits: ESA's SMARTCARB study, Empa

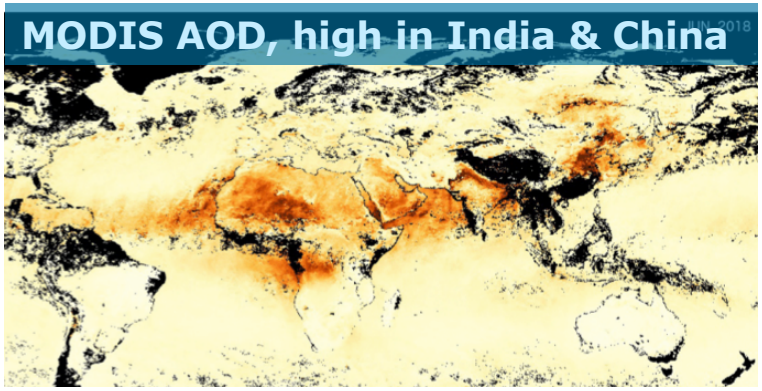
CO2M requirements – aerosol & clouds

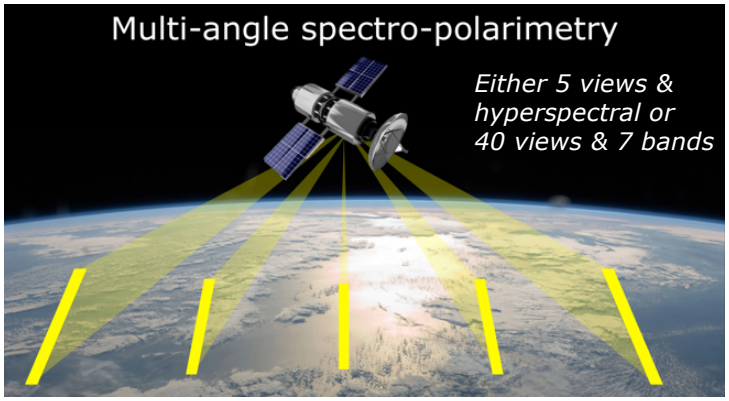
Aerosol & cloud scattering:

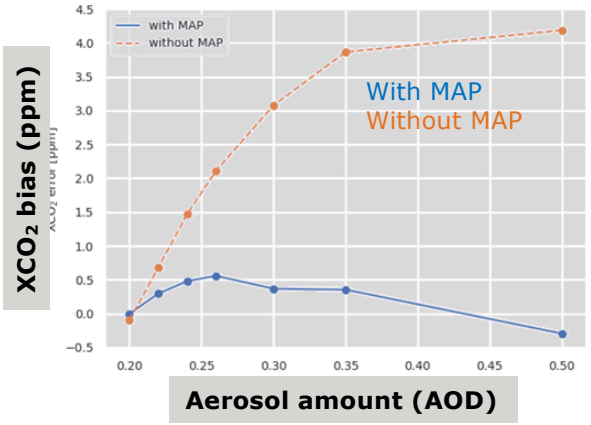
Light path correction is very important
Heritage missions filter for AOD<0.3
Thin cirrus & small cloud fractions → incompliant to XCO_2 error budget

For CO2M, light path correction by measuring effective aerosol & clouds:

- → **Higher accuracy CO_2 data (less posterior bias correction)**
- → **More data and also at higher aerosol loading; up to 0.5 AOD**
- → **Cloud cover of CO_2 pixel identified to 1 – 5% incl cirrus**



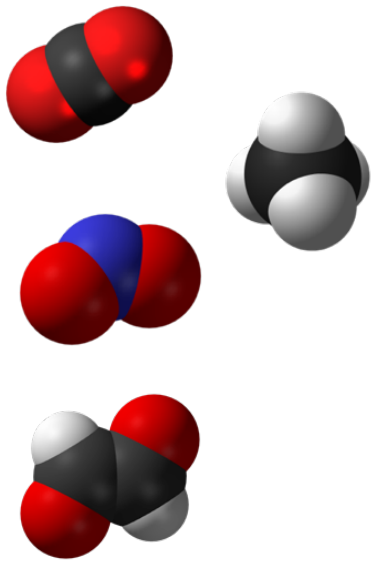




Credits:
ESA's Spectral Sizing study, SRON

CO2M Mission GHG & AQ Products

Product	Spatial	Precision
CO_2	4 km^2	0.7 ppm
CH_4	4 km^2	10 ppb
NO_2	4 km^2	$1.5x10^{15}$ molecules cm^{-2}
Aerosol params	16 km^2	0.05 AOD, 500 m LH
Glyoxal (potential)	4 km^2	To be estimated



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

Number of measurements: ~1.1 million

Number of clear sky retrievals: ~200.000

Level-2 product sizes: ~5 Gb/orbit

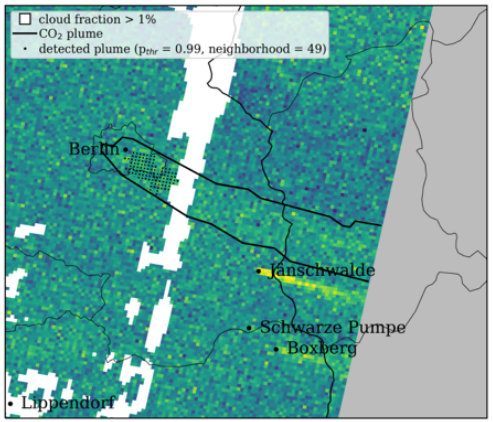
NB data for CO2M not required in NRT

BACKUP slides and FYI

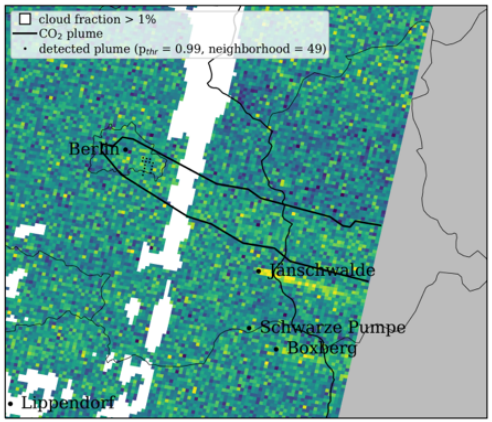
Detecting CO_2 plumes split by clouds

CO_2 retrieval only in cloud free conditions (here <1%)

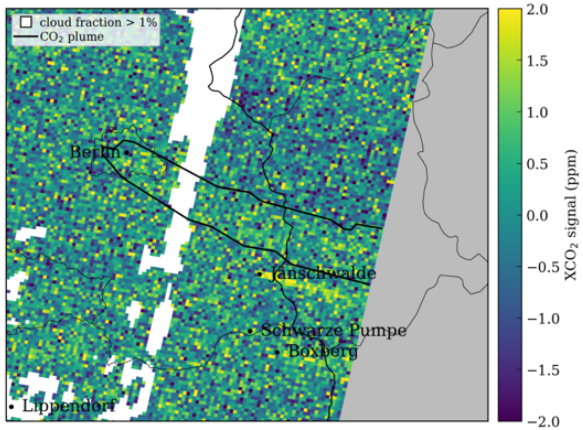
CO_2 (σ_{ref} = 0.5 ppm)



CO_2 (σ_{ref} = 0.7 ppm)

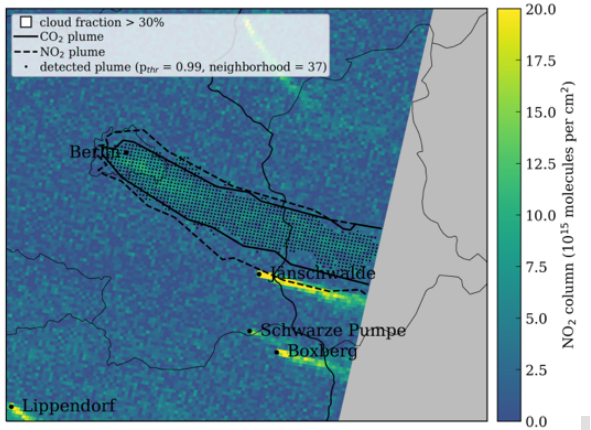


CO_2 (σ_{ref} = 1.0 ppm)

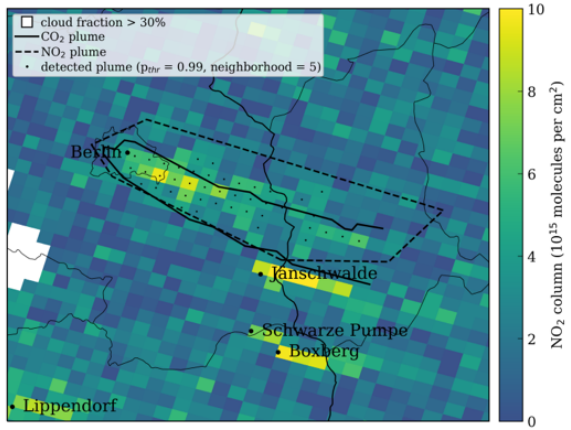


NO_2 retrieval also in cloudy conditions (here <30%)

NO_2 (σ_{ref} = 2×10^{15} cm^{-2})



NO_2 (Sentinel-5, 9 UTC)



Plume detection much better with NO2 for plumes split by clouds

Credits:
ESA's SMARTCARB study, Empa

CO_2 Monitoring – Space Segment Requirements 2/4

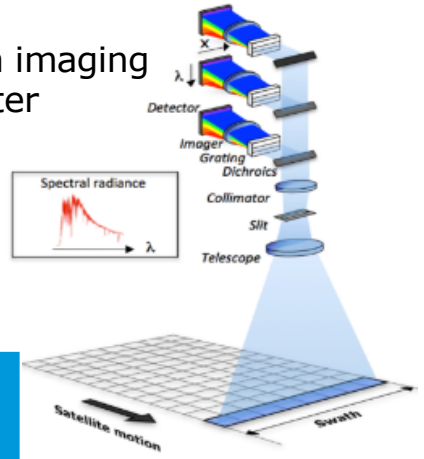
Mission requirements for XCO_2 & NO_2:

- Spatial co-registration: **95% overlap**
- Absolute radiometric accuracy: **3%**
- ISRF shape knowledge: **2%**

- **Spectral band requirements:**

Band	Spectral range	Spectral resolution	Spectral sampling ratio	SNR_{ref} @ L_{ref} (photons/s/nm/cm^2/sr)
VIS	405–490 nm	0.6 nm	3	750 @ 1.35×10^{13}
NIR	747–773 nm	0.12 nm	3	330 @ 6.4×10^{12}
SWIR-1	1590–1675 nm	0.3 nm	3	400 @ 2.1×10^{12}
SWIR-2	1990–2095 nm	0.35 nm	3	400 @ 1.8×10^{12}

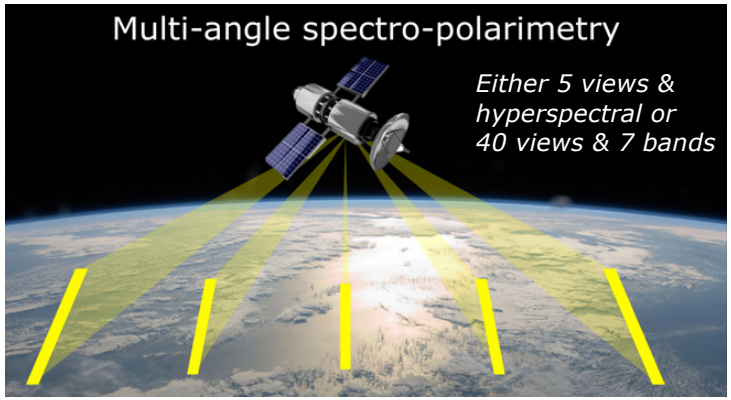
Pushbroom imaging spectrometer



CO_2 Monitoring – Space Segment Requirements 3/4

Aerosol data:

- **Multi-angle polarimeter (MAP)** for light path correction
- Either 5 views continuous band **or** 40 views multi-channel
- Observation zenith angle **+/- 60 degrees**
- Spatial resolution **4x4 km² @ 4x oversampling**
- Degree of linear polarisation (DoLP) total error **<0.0035**



MAP Band	Spectral range [nm]	L^{TOA} Spectral resolution	DoLP spectral resolution
UVN	385–770	5 nm	15–40 nm

MAP Channel	Central wavelength	Spectral width
VNIR-1	410 nm	20 nm
VNIR-2	443 nm	20 nm
VNIR-3	490 nm	20 nm
VNIR-4	555 nm	20 nm
VNIR-5	670 nm	20 nm
VNIR-6	753 nm	9 nm
VNIR-7	865 nm	40 nm

Cloud Imager (CLIM)

- Multi-channel imager (670, 753, 1370 nm)
- Spatial sampling **400 m**

CO_2 monitoring mission status & planning

- Mission Requirements Document (MRD), V2.0 released Sep 2019
  https://esamultimedia.esa.int/docs/EarthObservation/CO2M_MRD_v2.0_Issued20190927.pdf
- ESA funding successful in 12-2019
- Tender Phase B2C/D/E1 requires 2 (of 3) flight models ready by end Q2 2025 (!)
- Phase B2C/D/E1 proposals received (02-2020) & under evaluation
- Decision for approval expected at 1 July meeting of ESA's IPC
- Contract negotiations and KO in second half of 2020, then PDR end 2021
- EC to provide funding in MFF of 2021 for recurring units and launchers