State of play of the European Anthropogenic CO_2 Monitoring Mission

10 May 2018

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B. Pinty, H. Zunker (EC), with contributions from many experts


Copernicus

Service Component – led by EC

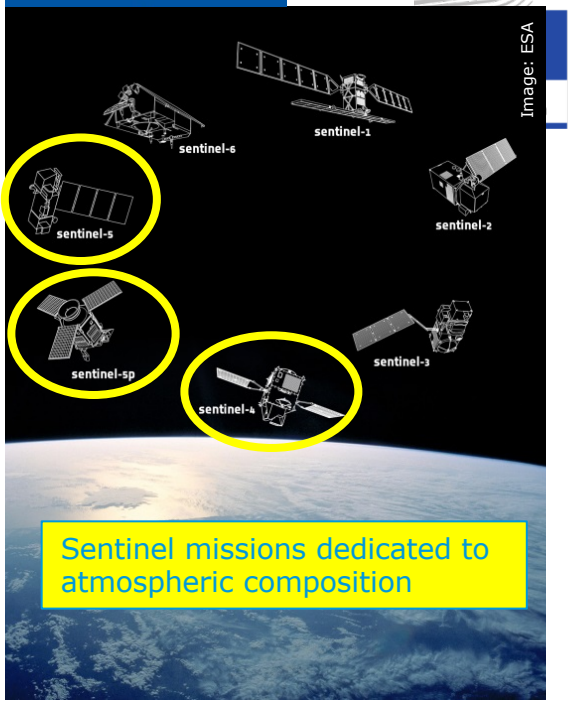
- Provides information services
- Relies on **in-situ** & **satellite components**

In-situ Component – led by EEA

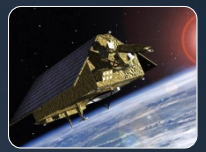
- Observations at national level

Space Component –led by ESA

- Sentinels – satellite missions specifically developed for Copernicus



European leadership – Sentinel missions

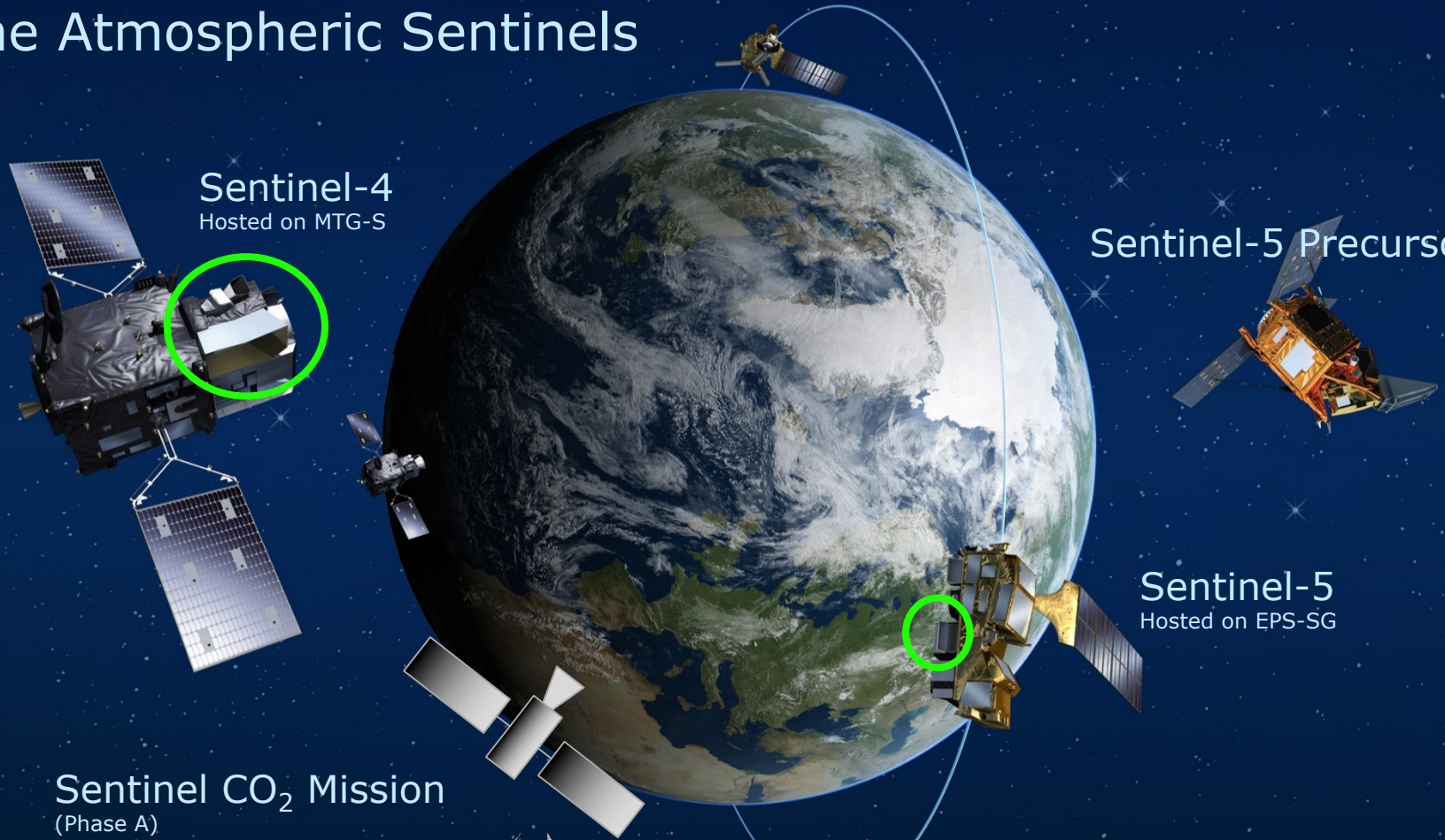
S-1	S-2	S-3	S-4	S-5P	S-5	S-6
						
Radar	High Resolution Optical	Medium Resolution Optical & Altimetry	Atmospheric Chemistry (GEO)	Atmospheric Chemistry (LEO)	Atmospheric Chemistry (LEO)	Altimetry
A 3 Apr. 2014	A 23 Jun. 2015	A 16 Feb. 2016	A 2021	A 13 Oct. 2017	A 2021	A 2020
B 25 Apr. 2016	B 6 Mar. 2017	B 25 Apr. 2018	B 2027		B 2027	B 2025

Copernicus Europe's eyes on Earth

European Commission


Atmospheric Composition

The Atmospheric Sentinels



Sentinel-4
Hosted on MTG-S

Sentinel-5 Precursor

Sentinel-5
Hosted on EPS-SG

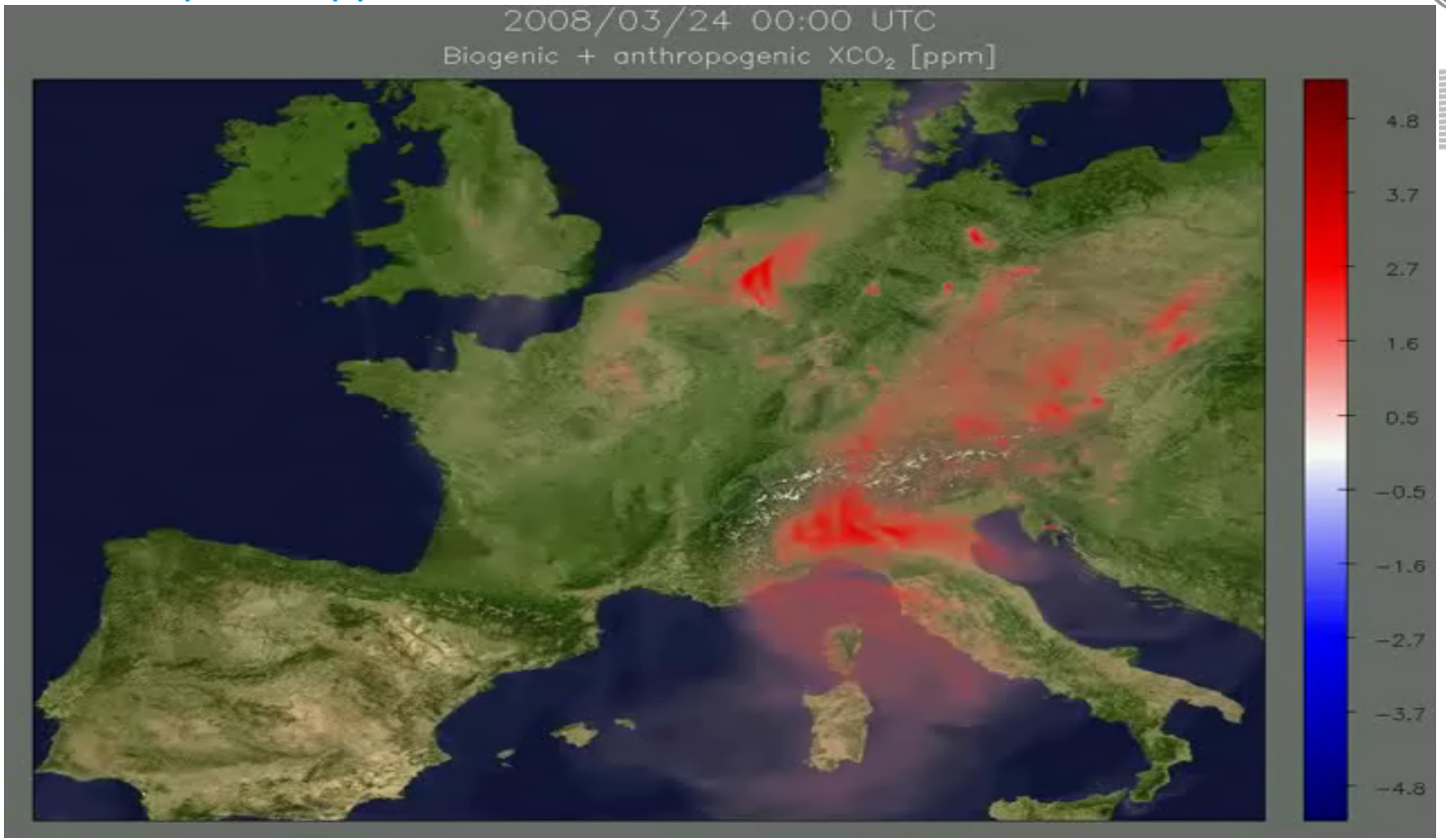
Sentinel CO_2 Mission
(Phase A)

Copernicus Europe's eyes on Earth | European Commission | EUMETSAT | esa


Copernicus Expansion

Top-down atmosphere approach

Simulation of total column CO_2 including emissions



European Commission

Credits: D Brunner, EMPA COSMO model

Candidate Copernicus Expansion Mission

End-to-end System requirements to monitor CO_2

Accuracy

1. **Detection of emitting hot spots** such as megacities or power plants.

2. **Monitoring the hot spot emissions** to assess emission reductions/increase of the activities.

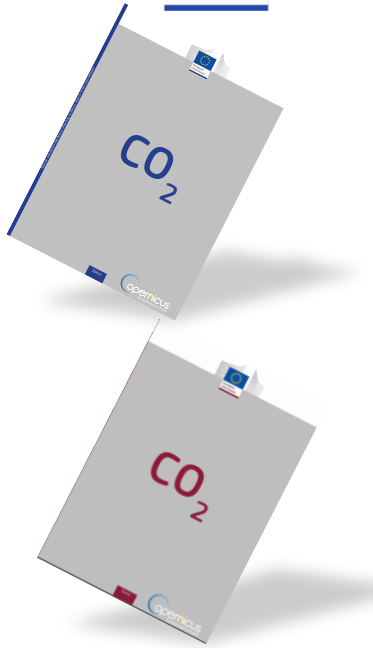
3. **Assessing emission changes against local reduction targets** to monitor impacts of the NDCs.

4. **Assessing the national emissions and changes** in 5-year time steps to estimate the global stock take.

200-400 ton/year

km & daily scales

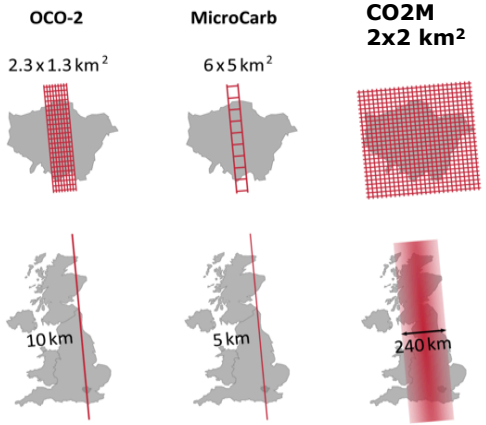
Space & Time



CO_2 Monitoring – Mission Requirements

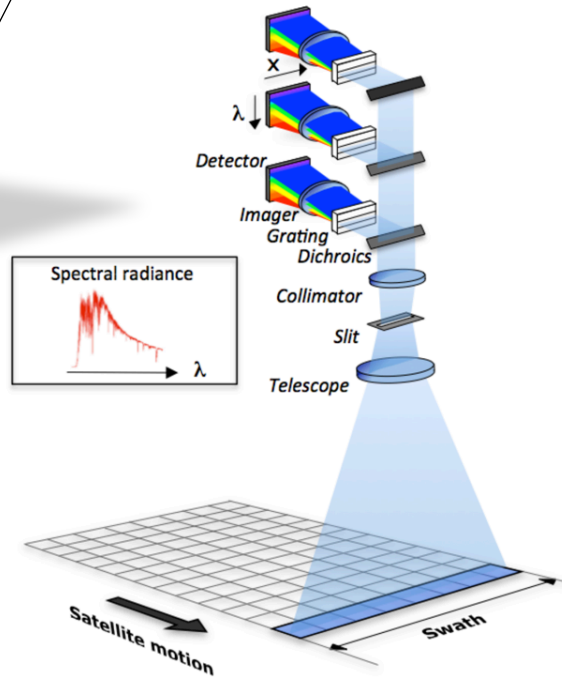
Mission requirements (XCO_2):

- XCO_2 precision: **0.5 – 0.7 ppm**
- Systematic bias **< 0.5 ppm**
- Spatial resolution **4 km²**
- Continuously sampled swath width of **> 200 km**
- Revisit around **2–3 days** (poleward of 40 deg) by **constellation of N satellites**
- Orbit equator crossing time **11:30 hrs**
- Push-broom imaging spectrometer (heritage)



Band	Spectral range [nm]	Resolution [nm]	SNR
NIR	747–773	0.1	300
SWIR-1	1590–1675	0.3	400
SWIR-2	1925–2095	0.55	400

CH_4

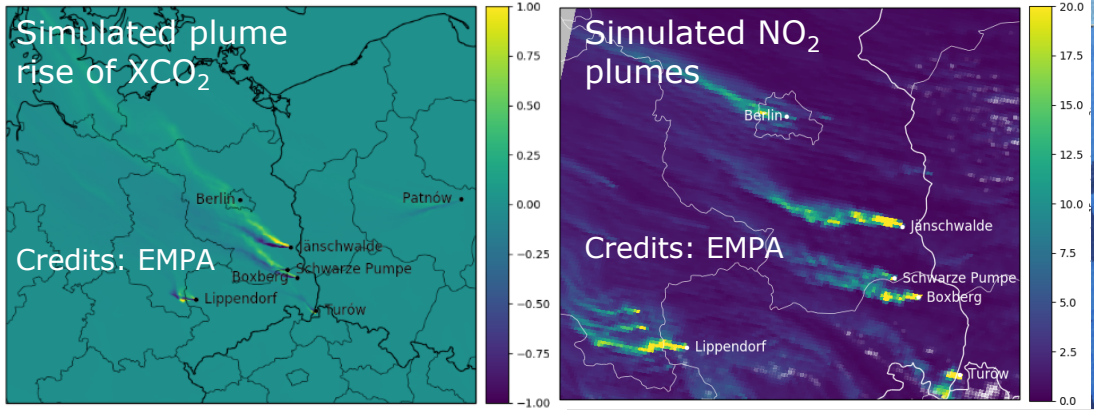


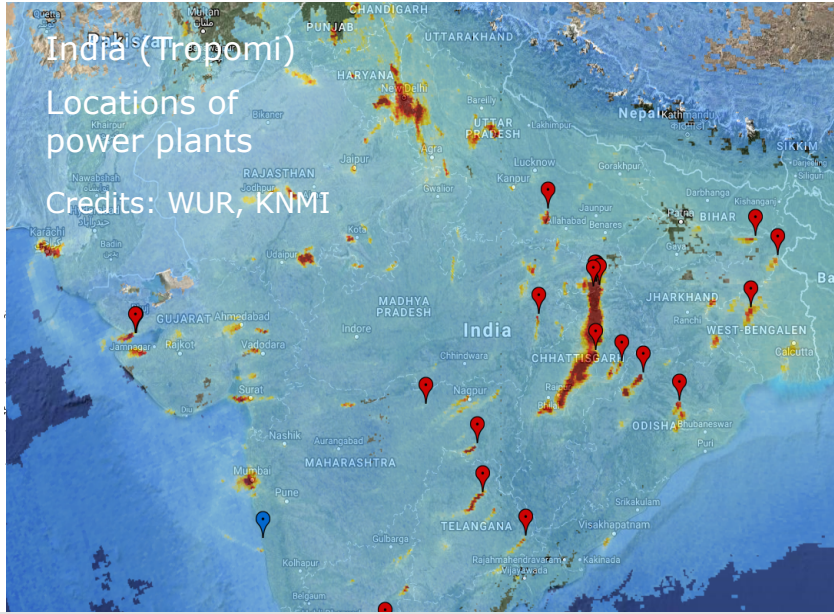
CO_2 Monitoring – Mission Requirements

Auxiliary requirements (NO_2):

- NO_2 precision: **1–2·10^{15} molec/cm^2**
- After resampling (same as for CO_2):
  - Spatial resolution **4 km^2**
  - Swath width **> 200 km**
- Push-broom imaging spectrometer (heritage)
- Trade-off: self standing vs embedded in CO_2 instrument

Band	Spectral range [nm]	Spectral resolution	SNR at reference radiance
VIS	405–490	0.6 nm	500





CO_2 Monitoring – Mission Requirements

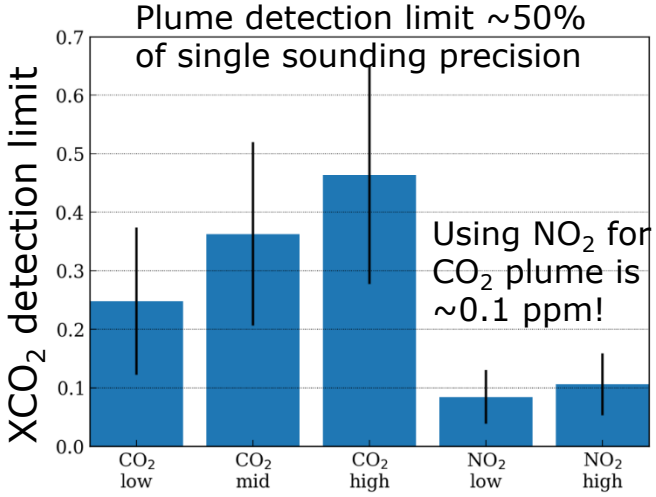
Auxiliary requirements (NO_2):

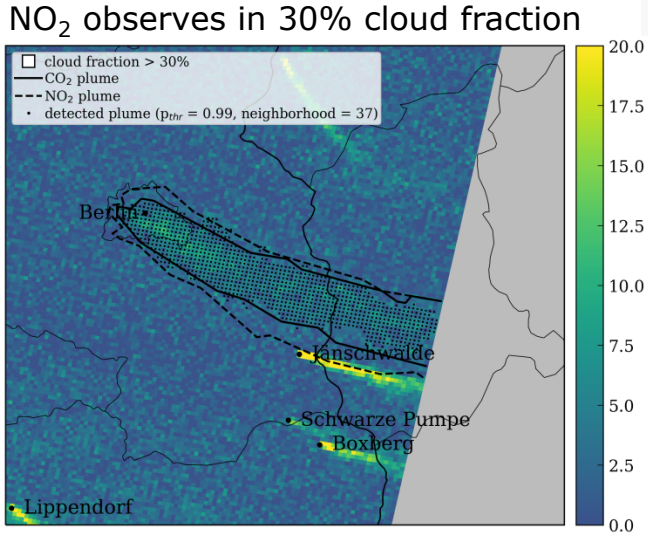
NO_2 plumes enhance CO_2 plume:

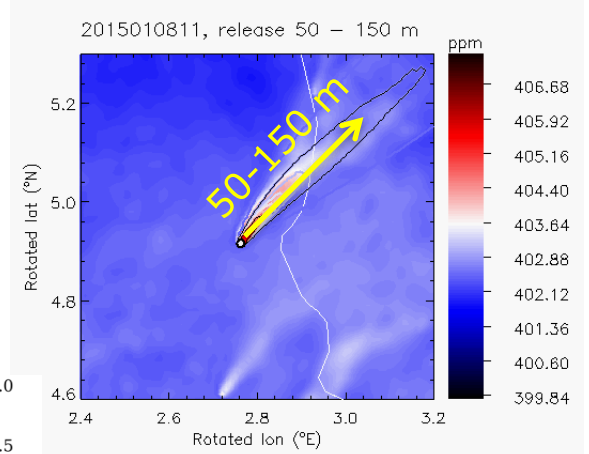
location, height & identification

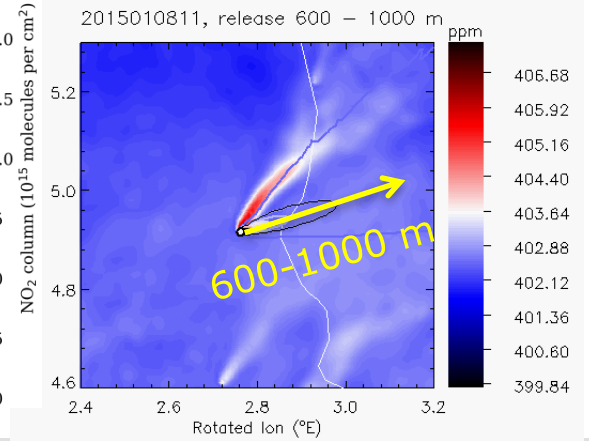
provides best matching 3D wind field

→ **more & better CO_2 emission estimates**









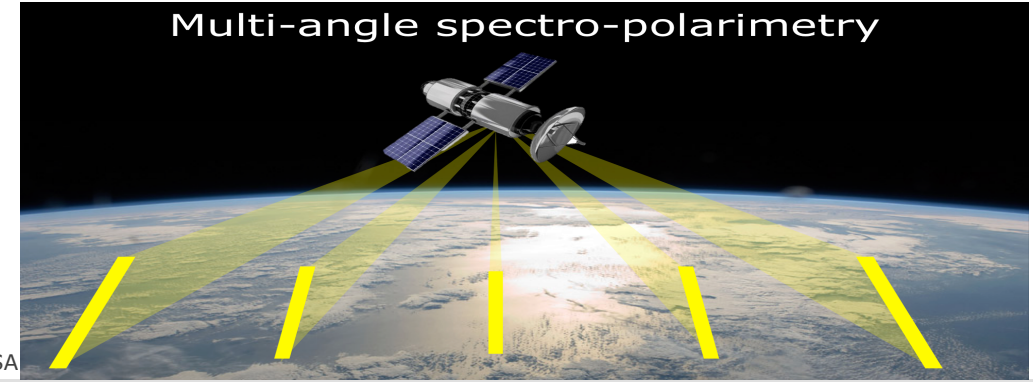
CO_2 Monitoring – Mission Requirements

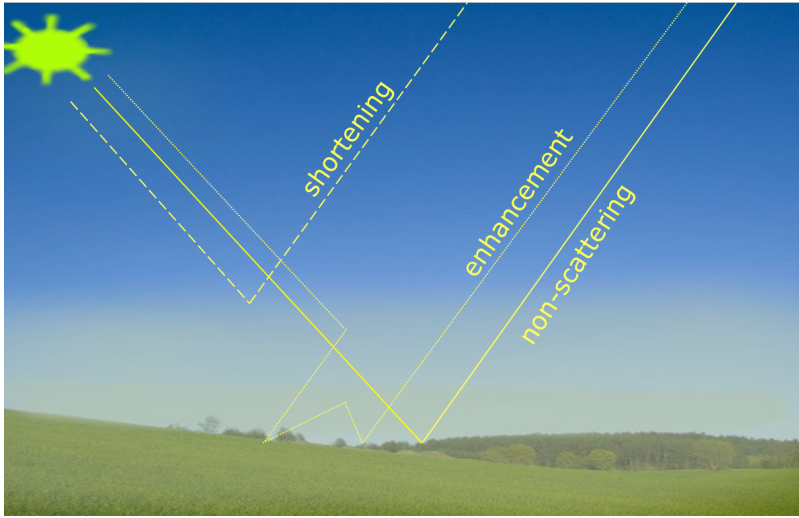
Auxiliary requirements (aerosol & clouds):

- Multi-angle polarimeter for light path correction
- After resampling (same as for CO_2):
  - Spatial resolution **4 km²**
  - Swath width **> 200 km**
- Measure degree of linear polarisation (DoLP)
- Observation zenith angle range **+/- 60 degrees**

European Commission

Band	Spectral range [nm]	Spectral resolution	DoLP spectral resolution
VIS	410–865	0.6 nm	20–40 nm





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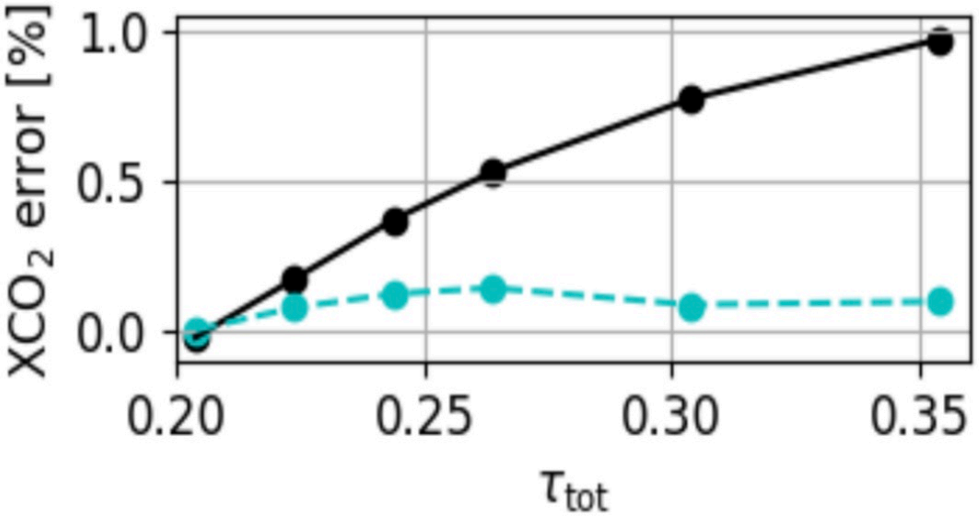


without MAP

with MAP

CO_2 monitoring mission: status & planning

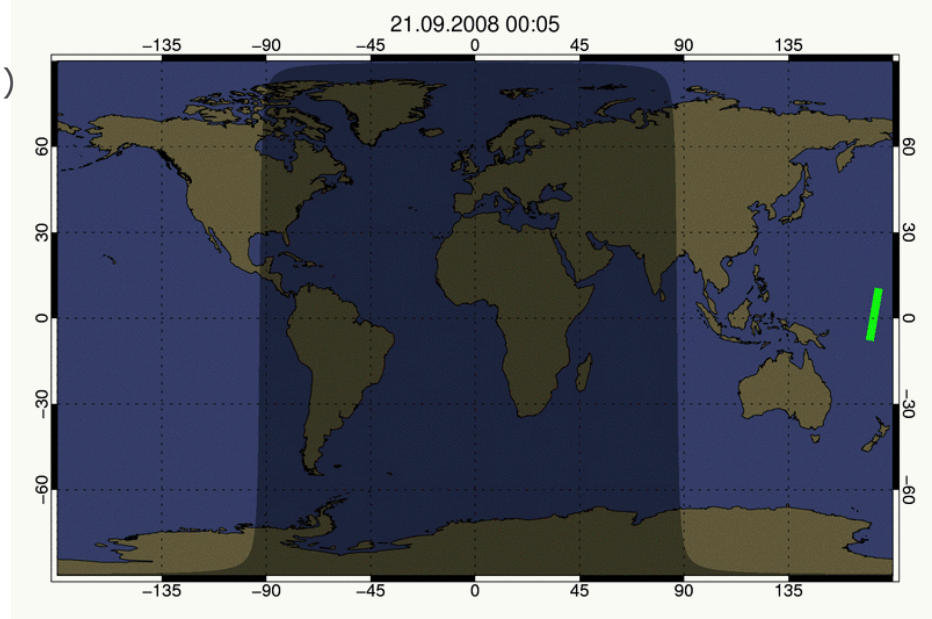
Constellation of 3 satellites is expected with about **250–350 km swath**
→ coverage requirement

Phase A/B1 system studies:
- 03-2018, two parallel studies started
- 01-2019. PRR (Preliminary Requirement Review)
- 07-2019, ISRR (Interm. System Requirement Review)
- Pre-developments continue to end 2019

Mission Advisory Group (MAG):
First meeting planned 12–13 June 2018

Roadmap:
- Budget required at C-MIN19 → end 2019
- Start implementation (Phase B2/C/D/E1) → Q1-2020
- Launch target in 2025–2026

CEOS AC-VC White Paper on GHG is applicable and offers opportunities



Credits: IUP, one-day animation

Virtual Constellation Opportunities

European Union intends to develop a **self-standing, robust and operational** monitoring capacity for anthropogenic CO_2 emissions

Complementary elements **enhancing this system:**

- High accuracy CO_2 **lidar** measurements → travelling standard
- Additional **LEO imager satellites** → enhancing observation frequency
- Ground-based **cal/val** observations in representative areas
- Improving retrieval **algorithms** & required **spectroscopy**
- Improving **flux inversion** algorithms

Thank you

Backup

CO_2 monitoring mission concept, status & planning

CO_2 & NO_2: technical concept deploys a push-broom imaging spectrometer (as heritage missions)

Aerosol & clouds: polarimeter measuring degree of linear polarization multiple angles along the flight track

Satellite constellation: to reach the coverage requirement a constellation of **3 satellites** with about 250 km swath is expected

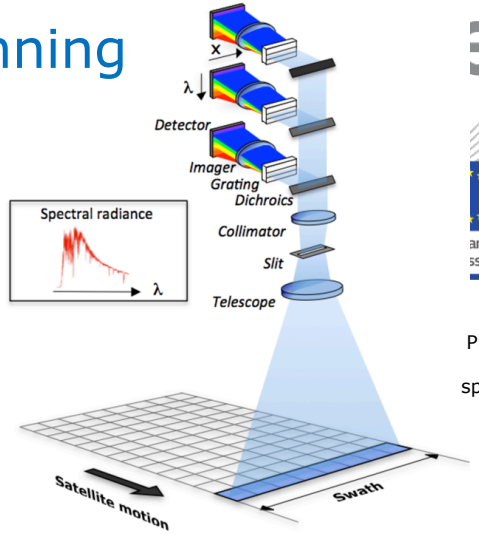
Two parallel **Phase A/B1** system studies: started 03-2018 to mid ’19

Mission Advisory Group established with first meeting 06-2018

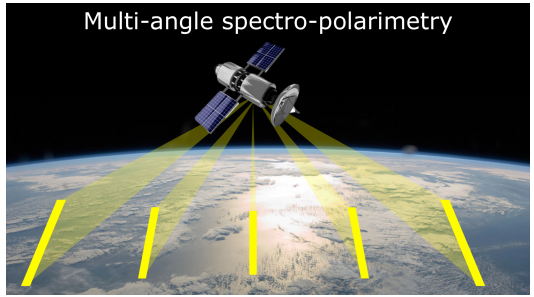
Start implementation (after confirmation at C-MIN19) → Q1-2020
Launch target in 2025–2026

CEOS AC-VC White Paper on GHG is applicable and offers opportunities

Several ESA and H2020 support studies



Push-broom imaging spectrometer concept



Credits: SRON

CO_2 Monitoring Mission Objectives & Requirements

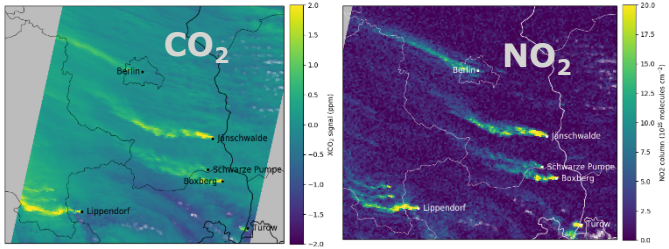
In support of the Paris agreement and required national policies, an anthropogenic CO_2 **monitoring & verification support** capacity shall allow

1) to detect future new hot spots,
2) to monitor and assess hot spots,
3) to assess emission changes, as expected from the NDCs,
4) to assess the emissions trends (change in stocktake with 5 year timesteps)

Observation Requirements (MRD version 1, 04-2018):

- Spatial resolution **4 km²** over swath width of ~250 km
- Revisit of **2–3 days** (poleward of 40 deg), equator crossing time 11:30 hrs
- **XCO_2** product with **0.5–0.7 ppm** precision & syst. bias <0.5ppm
- **NO_2** product with **$1–2·10^{15}$ molec/cm²**
- Multi-angle **polarimeter** (MAP) aerosol & cloud observations

Band	Spectral range	Spectral resolution
VIS	405–490 nm	0.6 nm
NIR	747–773 nm	0.1 nm
SWIR-1	1590–1675 nm	0.3 nm
SWIR-2	1925–2095 nm	0.55 nm
MAP	385–770 nm	20 nm (polarisation)



Credits: EMPA

Credits: C. Bottea/EEA

Towards an anthropogenic CO_2 Monitoring & Verification Support Capacity