The Future European CO_2 Monitoring Mission and the Need of a Multi-Angle Polarimeter to Characterize the Atmospheric Light Path

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Copernicus Sentinel missions

European Commission

esa

atmospheric missions

S-1

Radar

A 3 Apr. 2014

B 25 Apr. 2016

S-2

High Resolution Optical

A 23 Jun. 2015

B 6 Mar. 2017

S-3

Medium Resolution Optical & Altimetry

A 16 Feb. 2016

B 25 Apr. 2018

S-4

Atmospheric Chemistry (GEO)

A 2021

B 2027

S-5P

Atmospheric Chemistry (LEO)

A 13 Oct. 2017

S-5

Atmospheric Chemistry (LEO)

A 2021

B 2027

S-6

Altimetry

A 2020

B 2025

S-7

Candidate

CO_2 Monitoring Mission

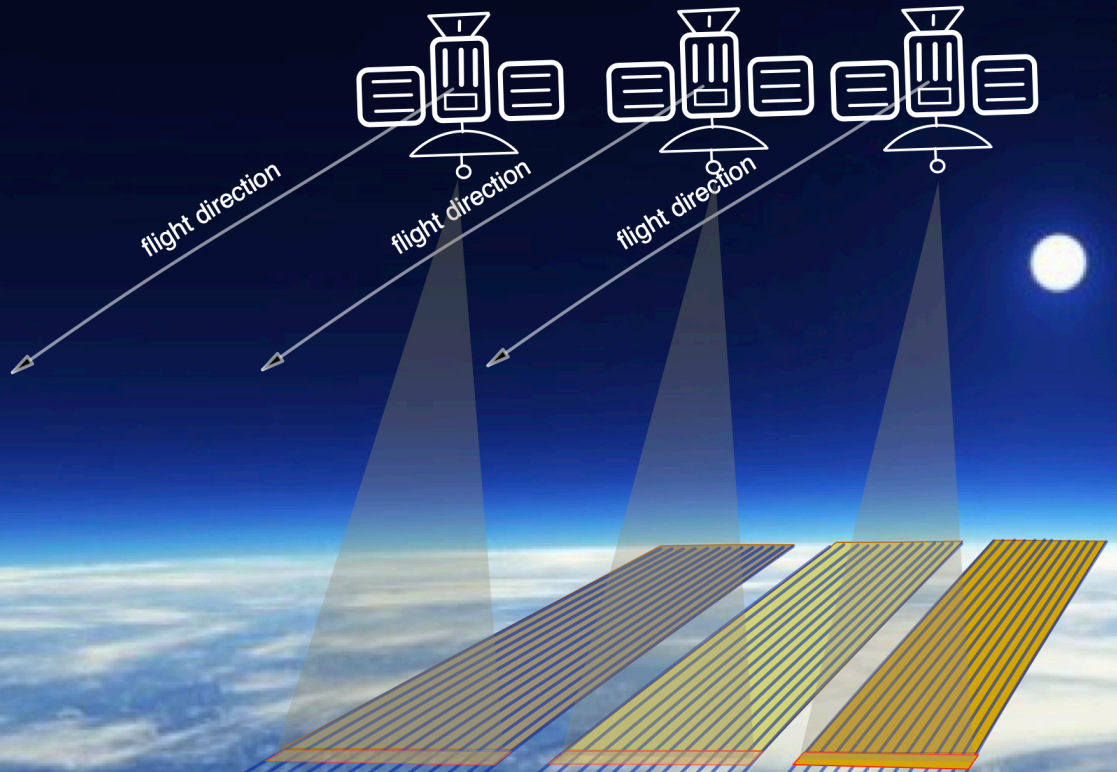
envisaged 2025

The Objectives of the CO_2 Monitoring Mission

- Detection and monitoring of emitting hot spots such as
  - megacities
  - power plants
- Assessing the national emissions and changes

Country ⟷ City ⟷ Power plants

CO_2 Monitoring mission



- Launch envisaged 2025
- Spatial resolution 4 km^2
- Revisit around 2–3 days (poleward of 40 deg)

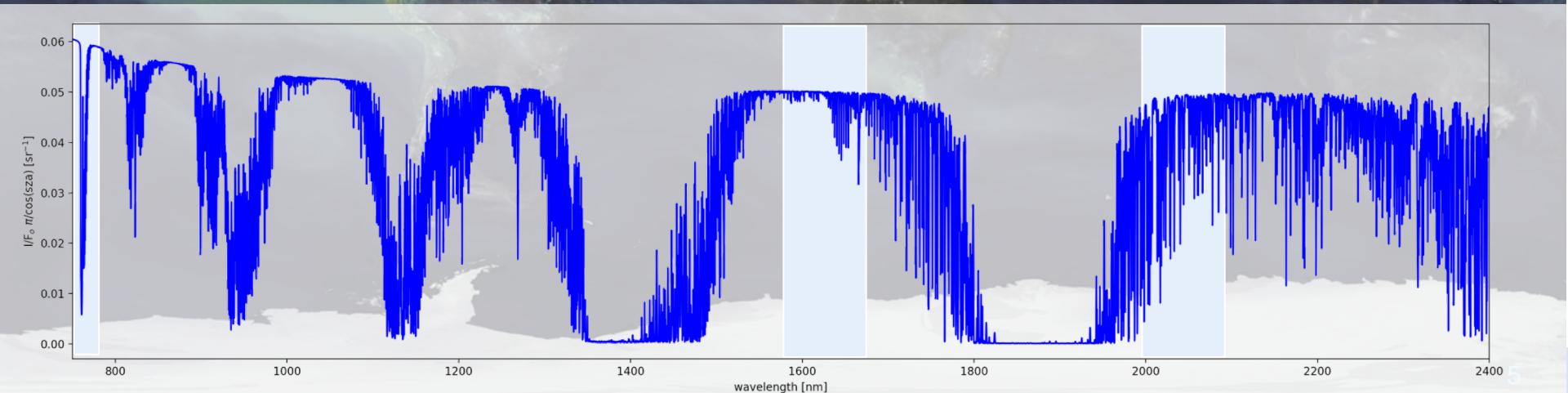
CO_2 Monitoring mission

- XCO_2 precision: 0.5 – 0.7 ppm
- Systematic bias: < 0.5 ppm
- CO_2I spectrometer: 3 band concept with moderate spectral resolution

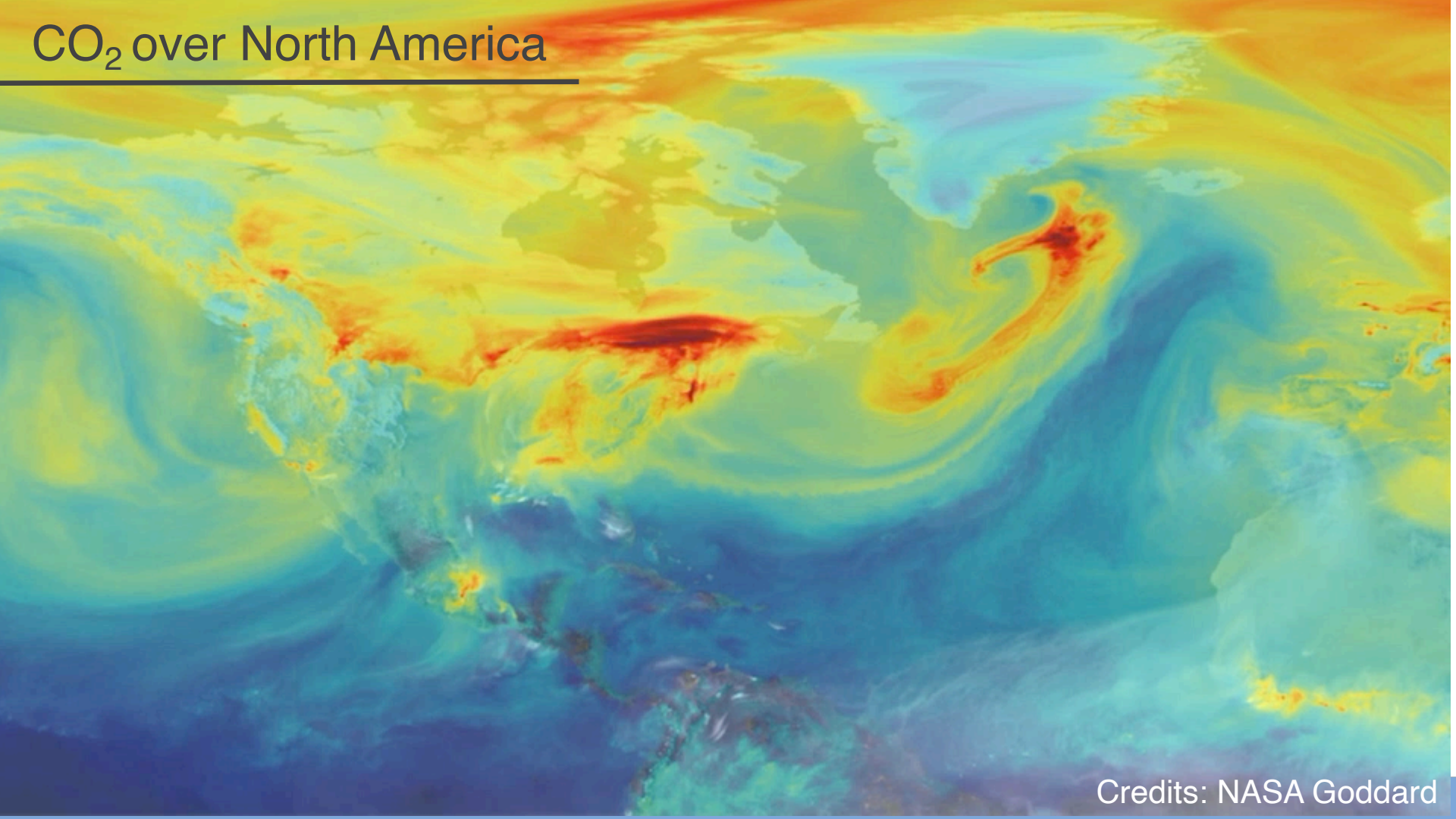
747-773 nm

1590-1675 nm

1990-2095 nm



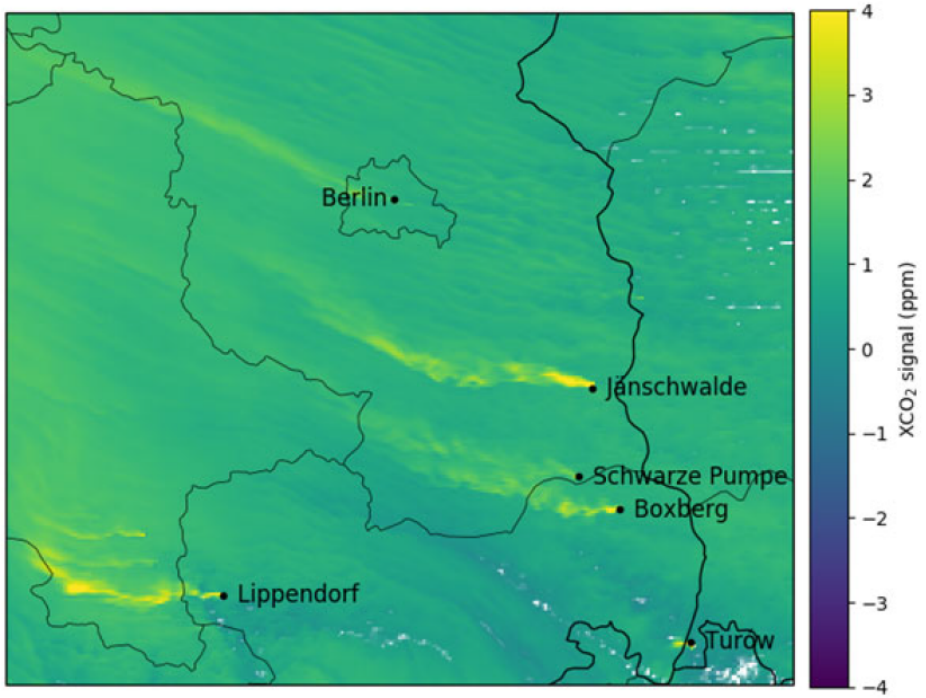
CO_2 over North America



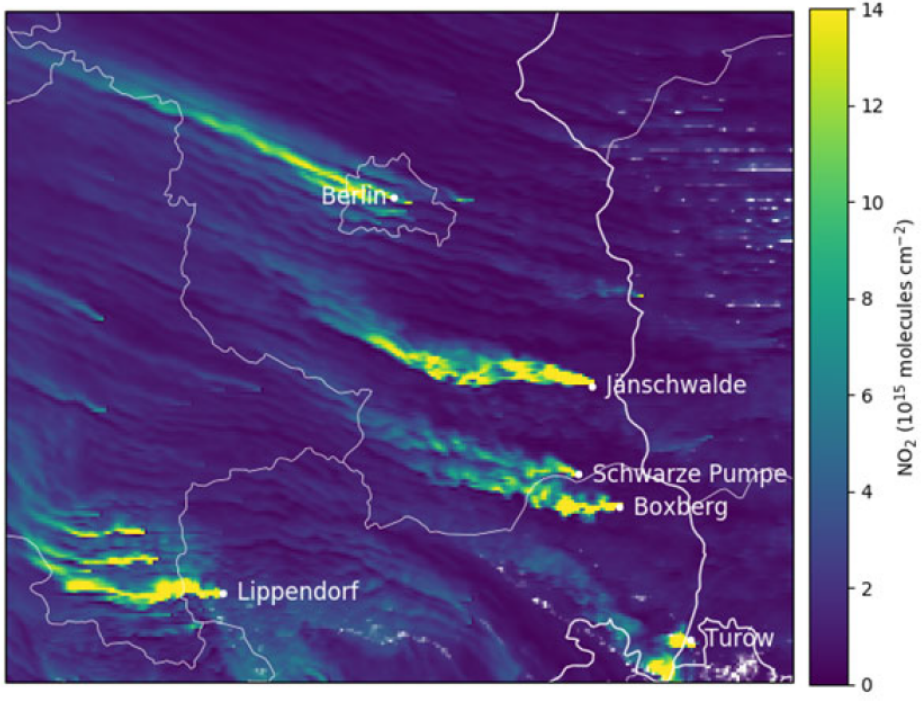
Credits: NASA Goddard

NO_2 spectrometer: NO_2 to detect CO_2 plumes

XCO_2

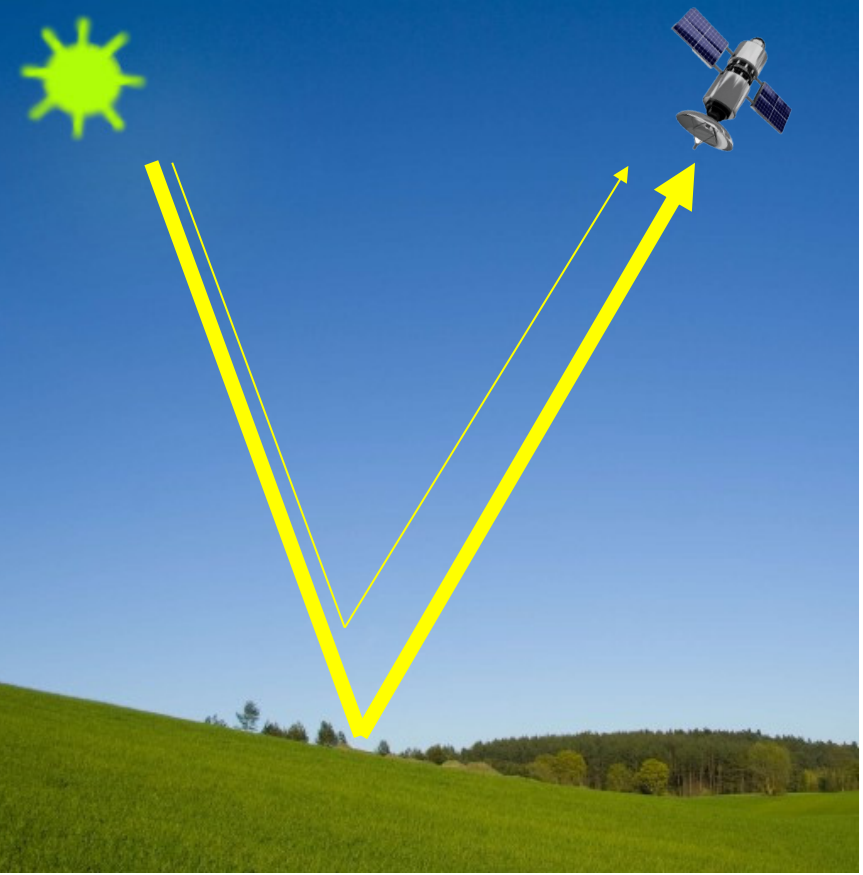


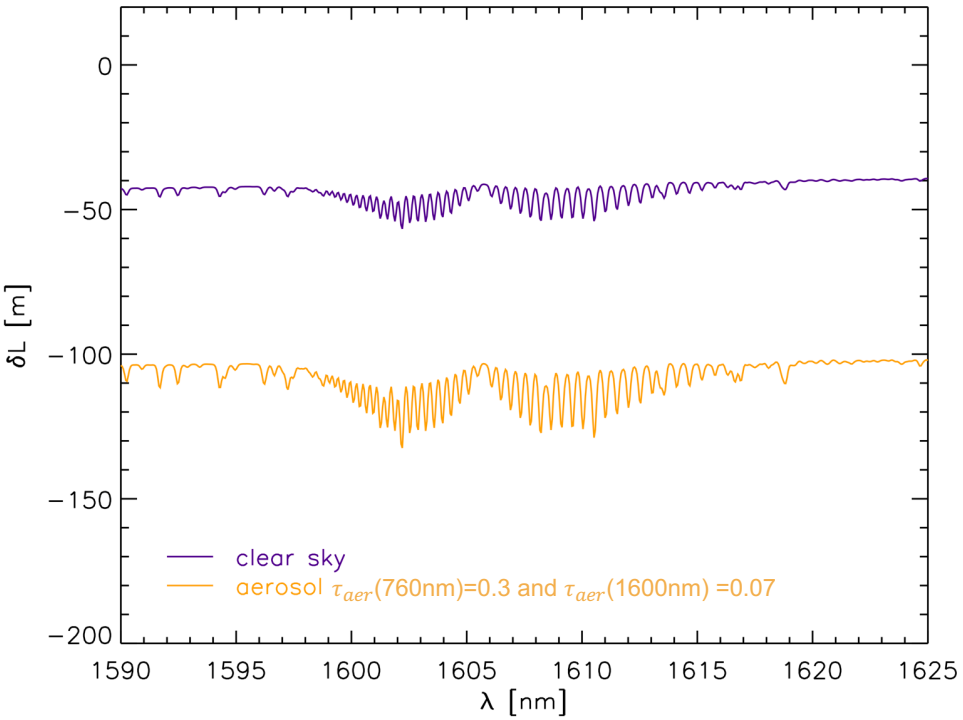
NO_2



Credits: SMARTCarb study, Brunner et al.

Change of light path





A change of the light path of 13 meter in the lowest 1 km of the atmosphere can cause an error of 0.5 ppm on XCO_2.

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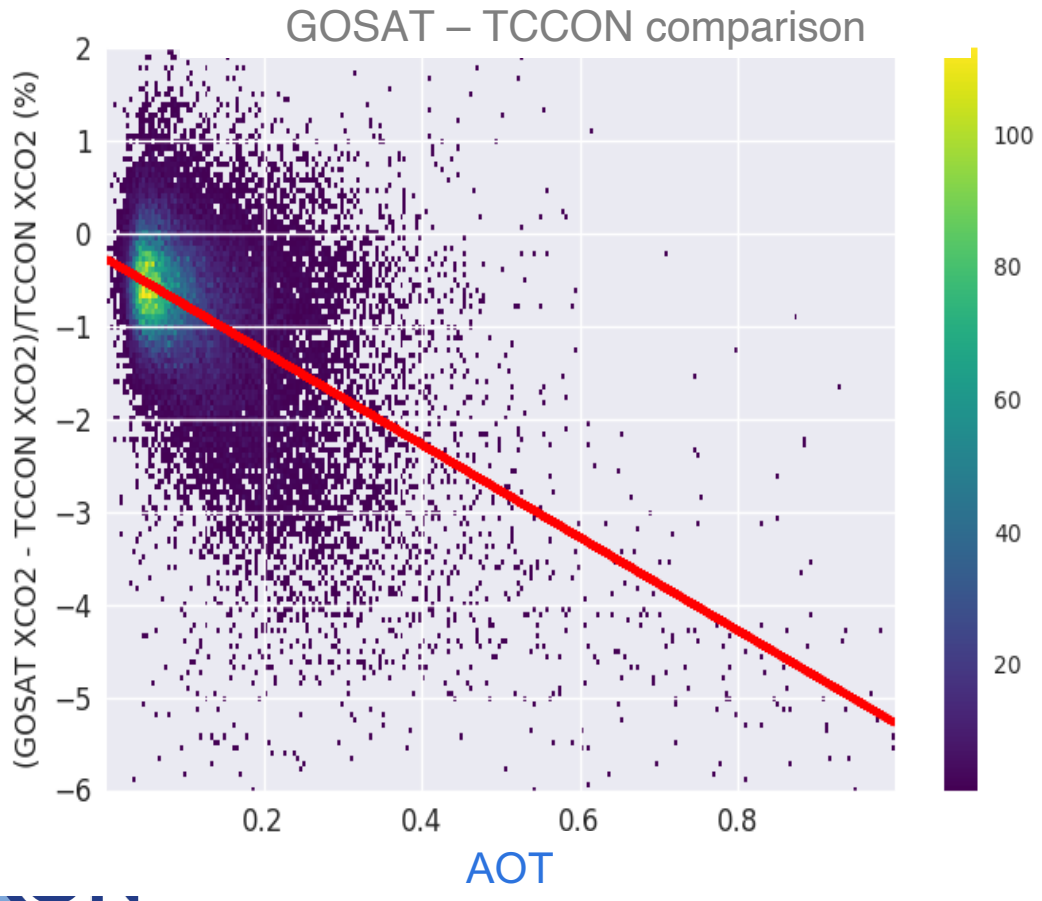
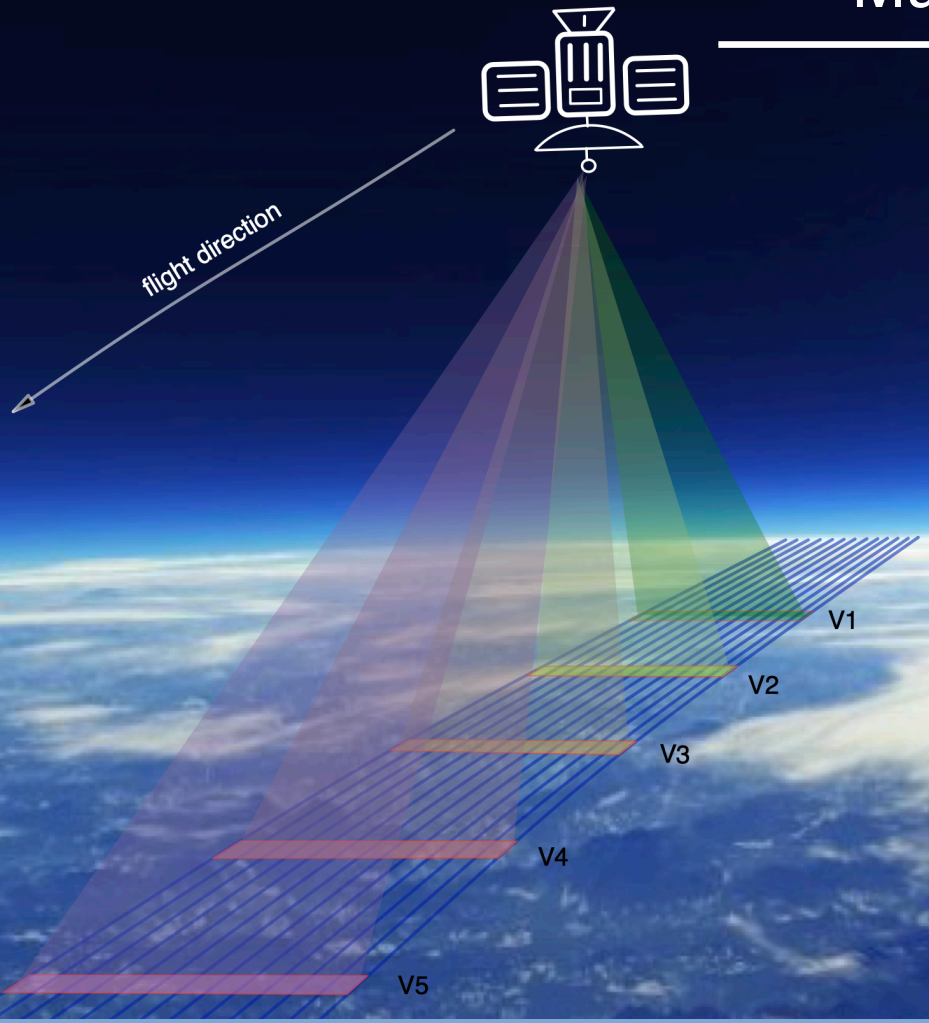
Aerosol induced CO_2 error



GOSAT-TCCON comparison without a posteriori aerosol filtering shows a clear bias dependence on aerosol optical depth.

Multi-Angle Polarimeter (MAP)



Concept one
Spec. range: 380-770 nm
Number of viewing angles: 5

Concept two
Spec. range: 7 bands
Number of viewing angles: 40

Challenging requirement:
DoLP accuracy ≤ 0.0035

CO2I-MAP joint retrieval approach

- Iterative aerosol CO_2 retrieval code for multi-angle radiance and polarization measurements and single viewing NIR/SWIR measurements
- The state vector:

	r_{eff}	v_{eff}	m_r	m_i	N	f_{sph}	z_{lay}
fine mode						X	X
coarse mode							

r_{eff}: effective radius
v_{eff}: effective variance
(m_r,m_i): refractive index
N: total number column
f_{sph}: fraction of spheres
z_{lay}: layer height

- Trace gas concentration CO_2, CH_4, H_2O and BDRF parameters

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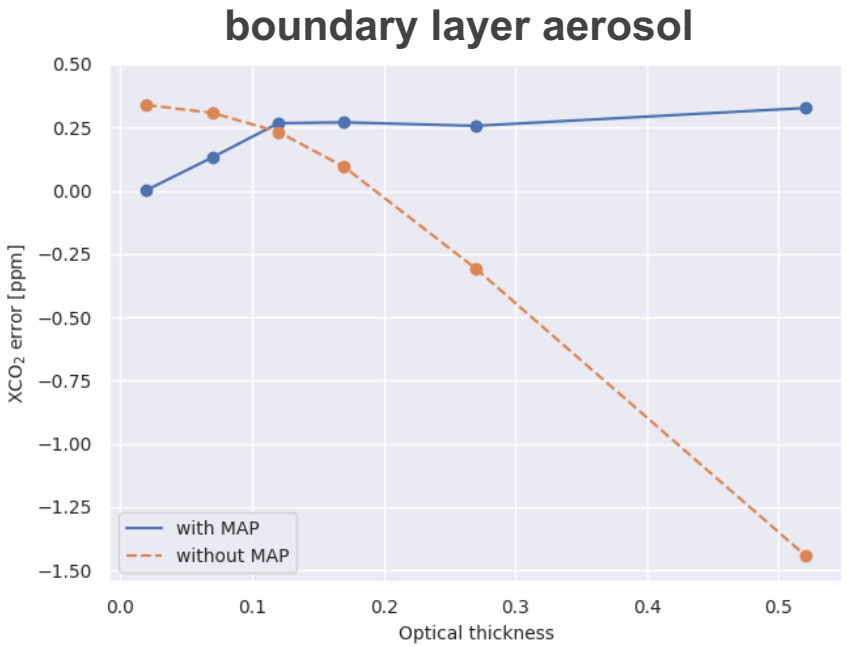
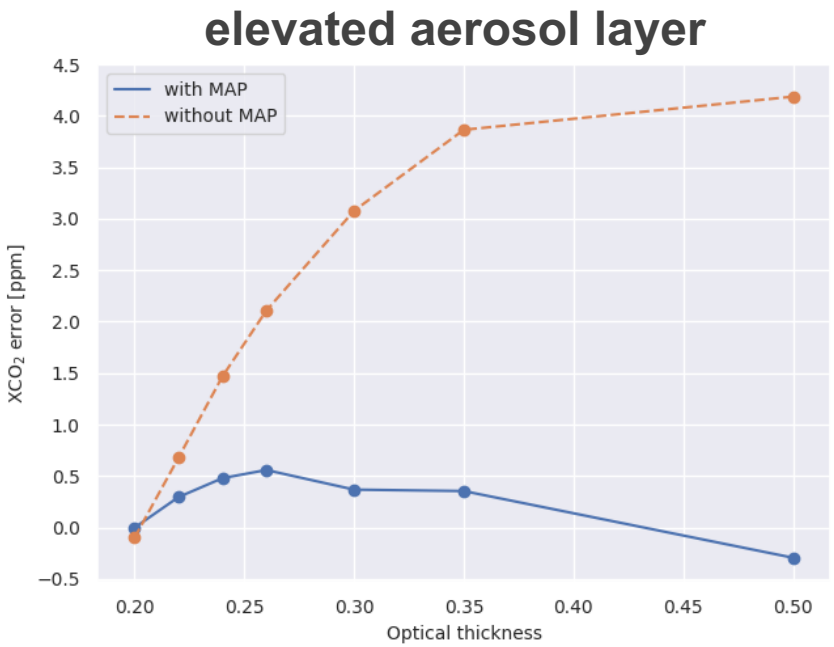
CO_2 performance with and without MAP





ENSEMBLE randomized in atmospheric parameter

500 instances randomized uniformed distribution

parameter	range
BRDF	soil-vegetation
Size distribution	Effective radius and variance, fine and coarse mode
Refractive index	Random mixture between inorganic matter and black carbon/ dust for fine/coarse mode
AOD@550 nm	$0.005 < \tau_{fine} < 0.7$ and $0.003 < \tau_{coarse} < 0.3$
Aerosol layer height	1-8.5 km
H_2O, CH_4, CO_2	$\pm 3\%, \pm 5\%, \pm 6\%$ profile scaling
Geometry	10^o<SZA<70^o

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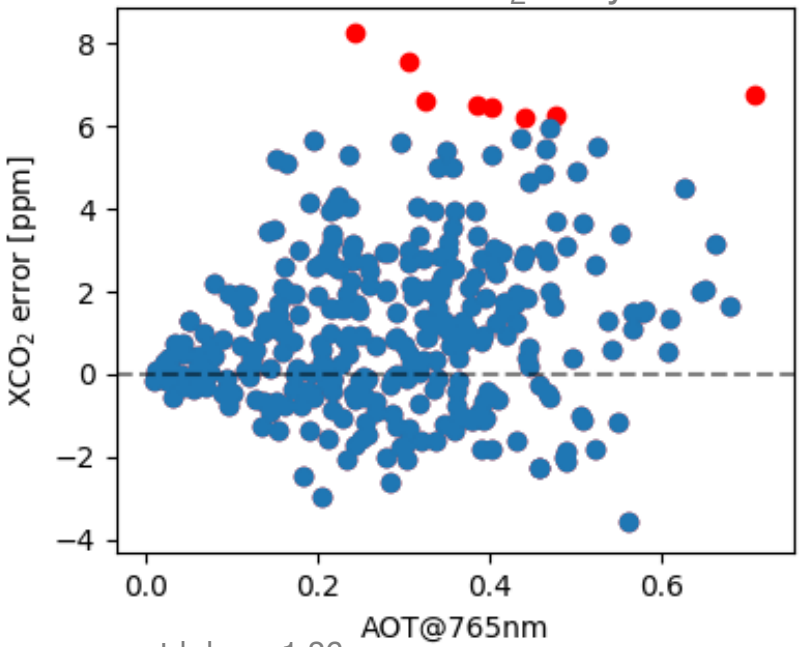
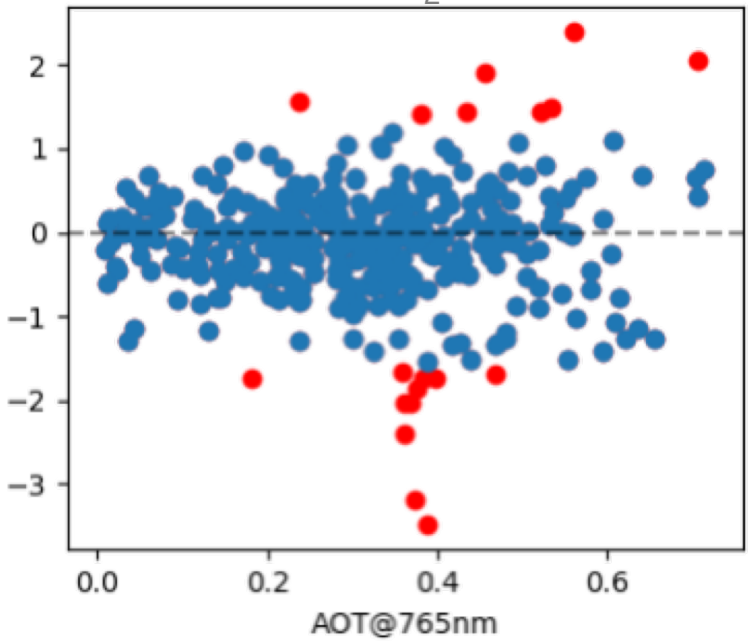
XCO_2 bias: dependence on AOT

CO_2I only retrieval



std dev. =1.86 ppm
median bias = 0.95 ppm

Joint CO_2I+MAP retrieval



std dev. =0.57 ppm
median bias = -0.088 ppm

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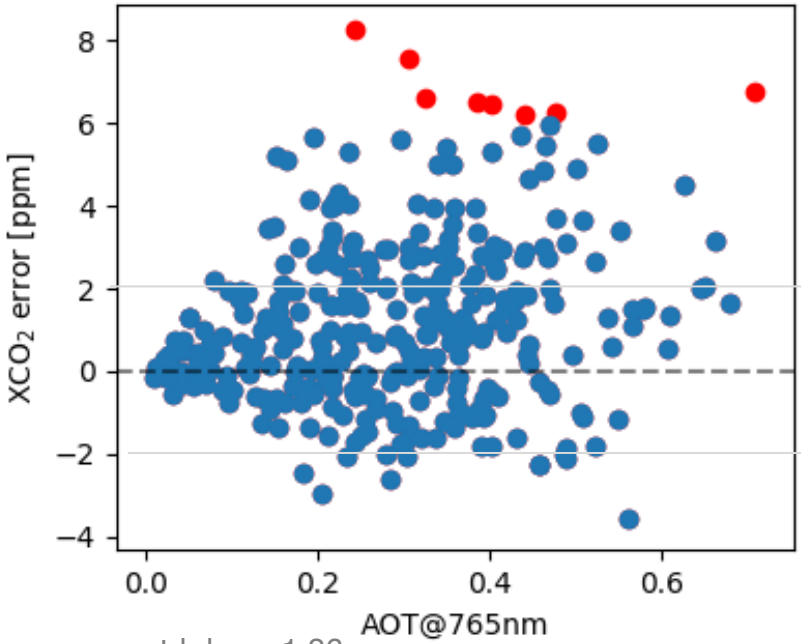
XCO_2 bias: dependence on AOT

CO_2I only retrieval



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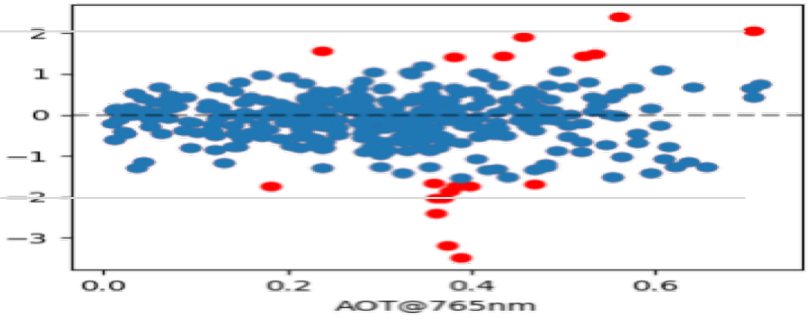

std dev. =0.57 ppm
median bias = -0.088 ppm

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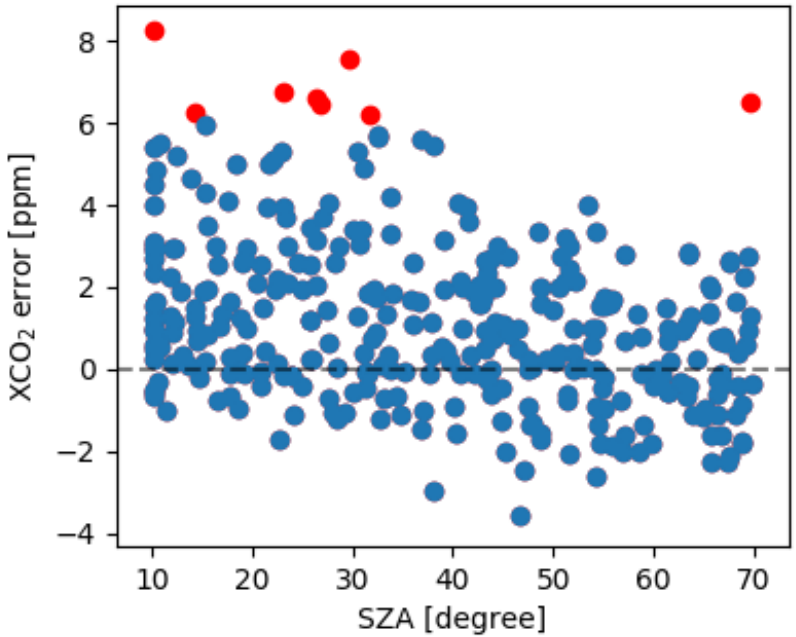
XCO_2 bias: dependence on SZA

CO_2I only retrieval



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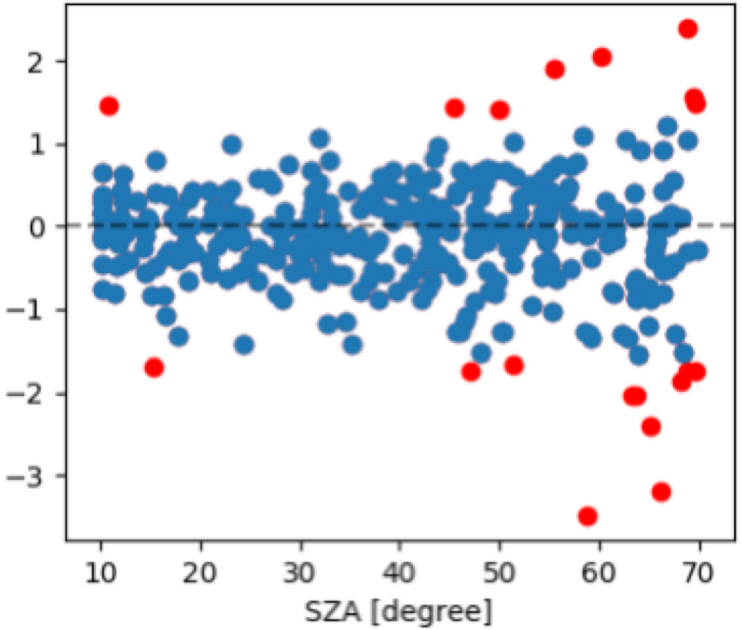

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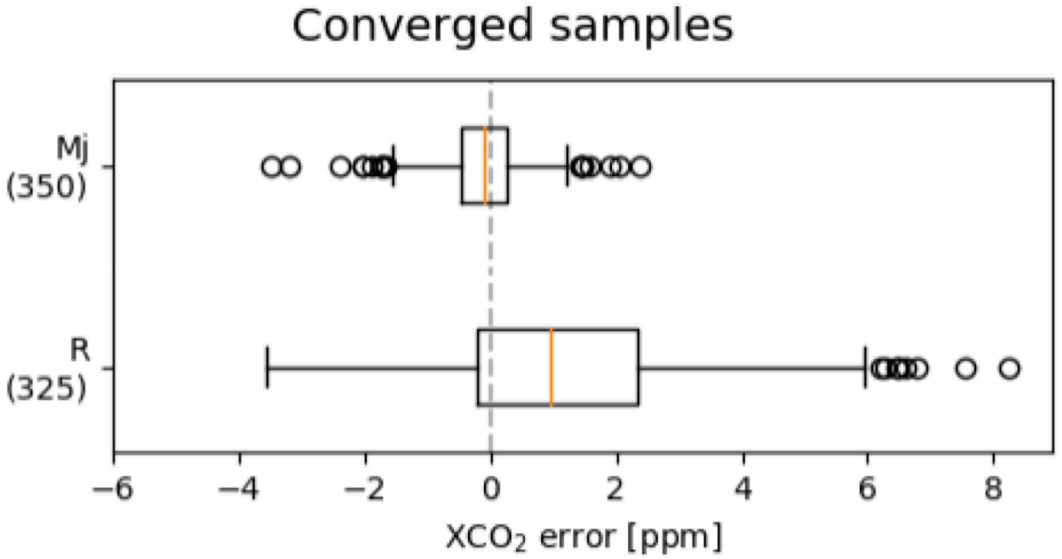
Box plot (total CO_2 error)



joint MAP/CO_2I retrieval

CO_2I only retrieval

Conclusions

- CO2M Sentinel 7 candidate mission comprises
  - CO_2 spectrometer (3 band: 760nm, 1.6μm, 2.0 μm)
  - NO_2 spectrometer (Vis, 405-465 nm)
  - Multiangle polarimeter (UV-Vis, 380-770nm)
  - Cloud imager (3 spectral bands incl. 1.38 μm)
- ITT for phase B2/C/D phase, launch 2025
- CO2M will provide a high-quality aerosol product with global coverage

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