Quantifying localized carbon dioxide emissions from space: the CO2Image demonstrator

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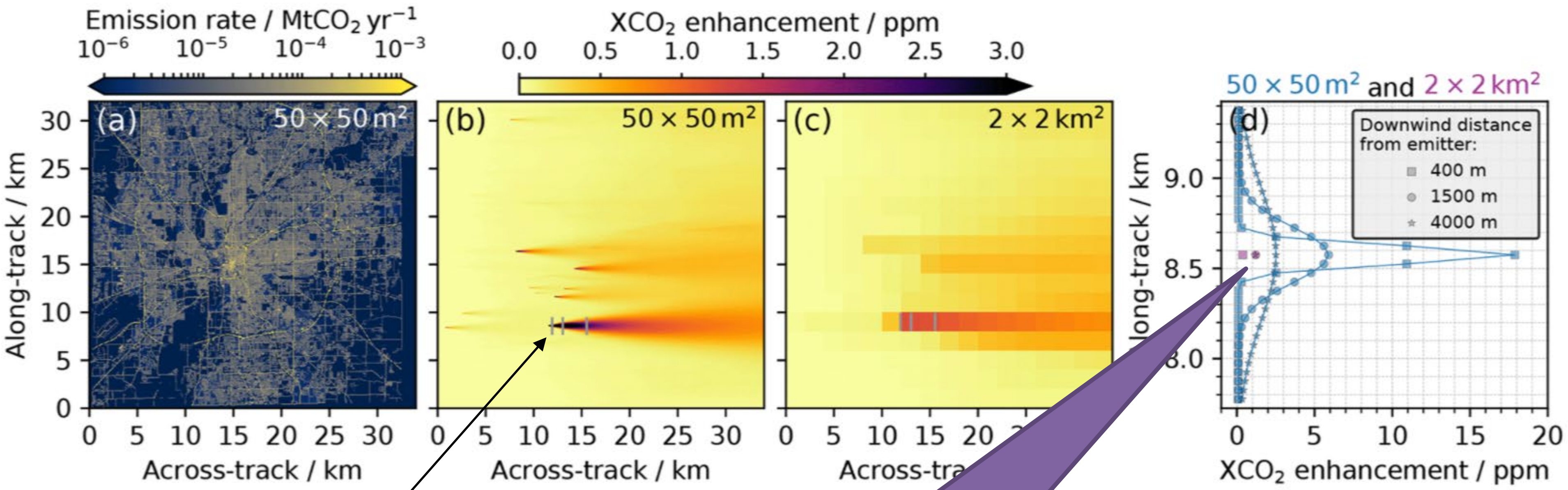
CO2Image targets this problem with a high-resolution approach

- Gaussian plumes simulated for the city of Indianapolis, at the resolution of CO2Image and CO2M (from Strandgren et al., AMT, 2020)



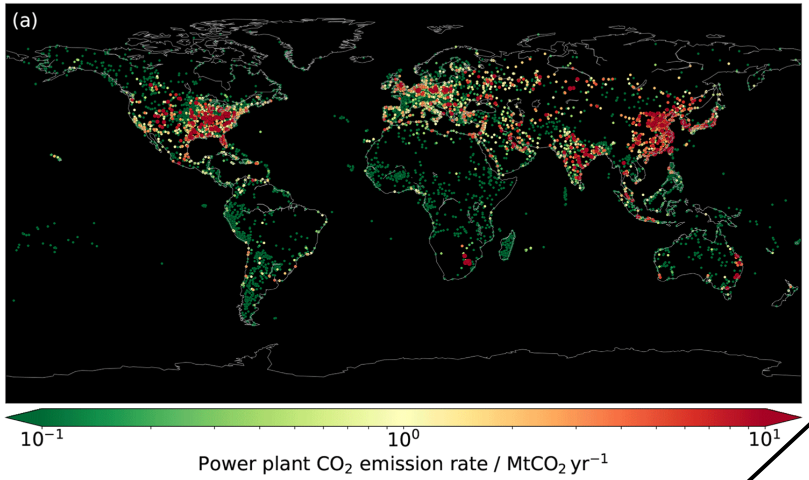
3.29 $MtCO_2$/yr

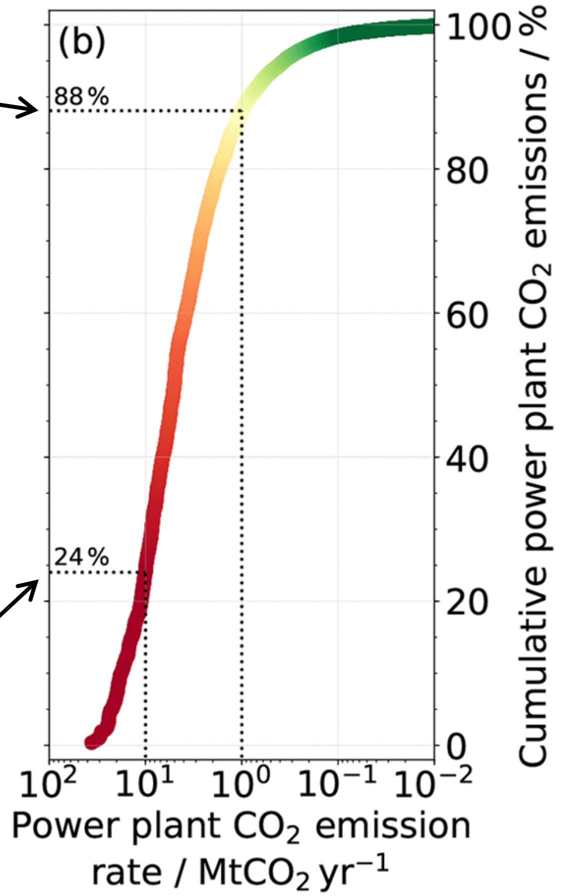
Leads to a very demanding measurement precision for CO2M!

Higher spatial resolution → quantification of smaller point sources

- A higher sensitivity (**down to 1 $MtCO_2$/year**) means that a higher proportion of point sources would be quantifiable based on remote sensing measurements:
  - A sensitivity threshold of > 10 $MtCO_2$/year could resolve 24% of emissions from coal-fired powerplants worldwide
  - A **sensitivity threshold of > 1 $MtCO_2$/year could resolve 88%** of emission from coal-fired powerplants worldwide

Quantification threshold of 1 $MtCO_2$/hr



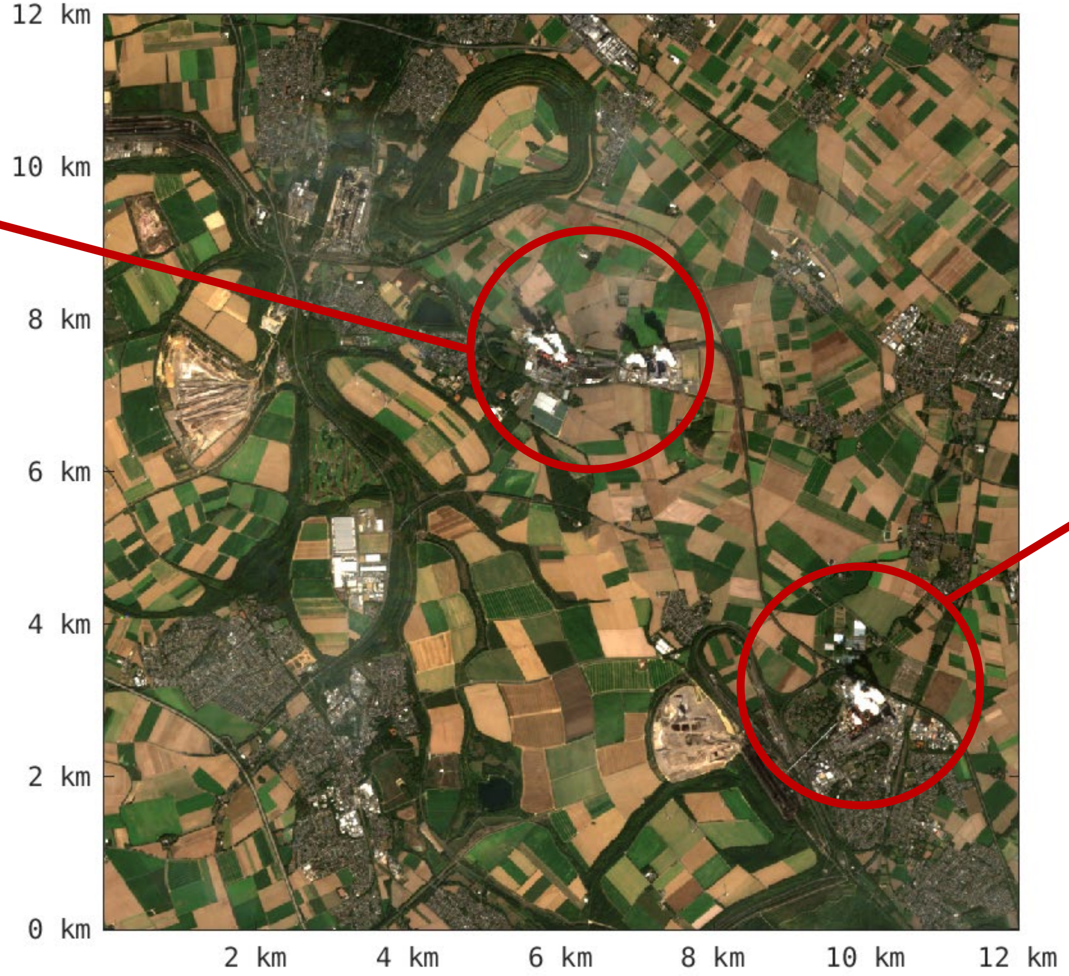


Quantification threshold of 10 $MtCO_2$/hr

from [Strandgren et al., AMT, 2020]

An example for power plants near Cologne

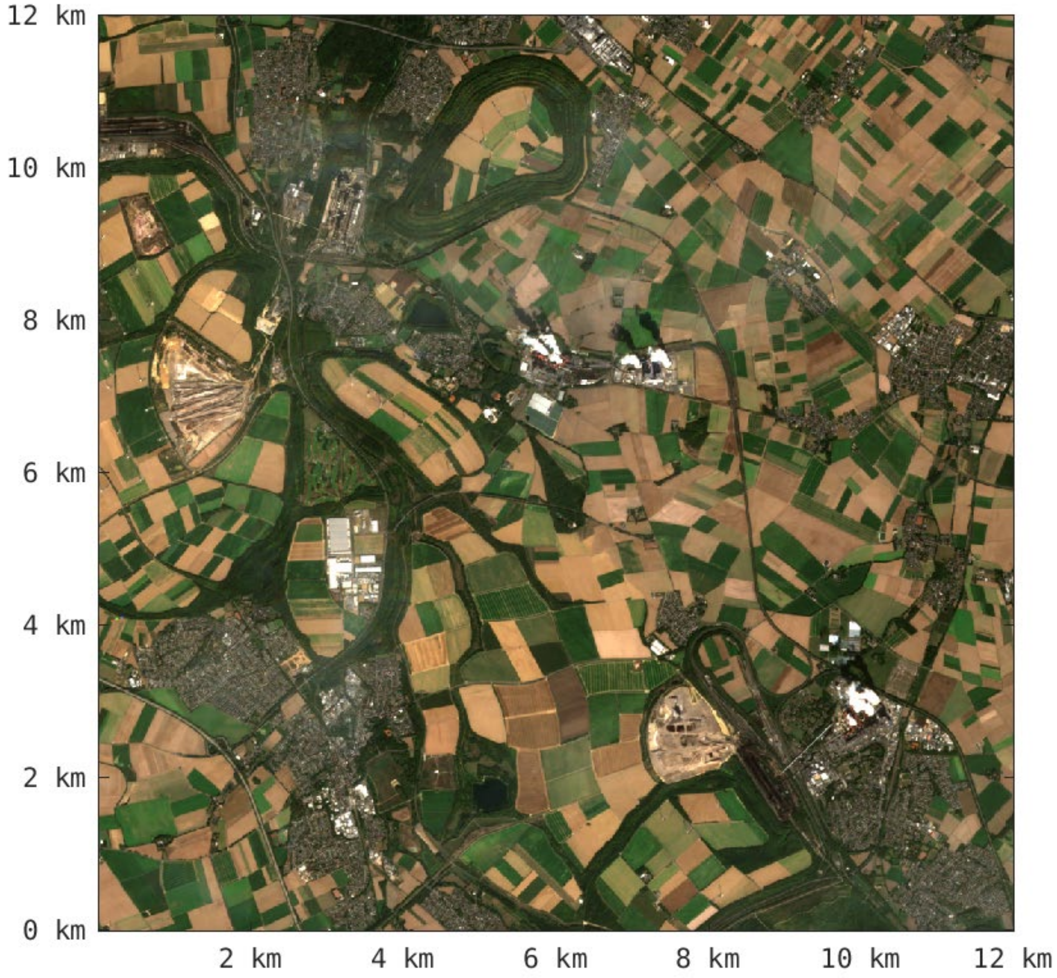
Neurath
Total emissions:
26 Mt CO_2/year



Niederaußem
Total emissions:
29 Mt CO_2/year

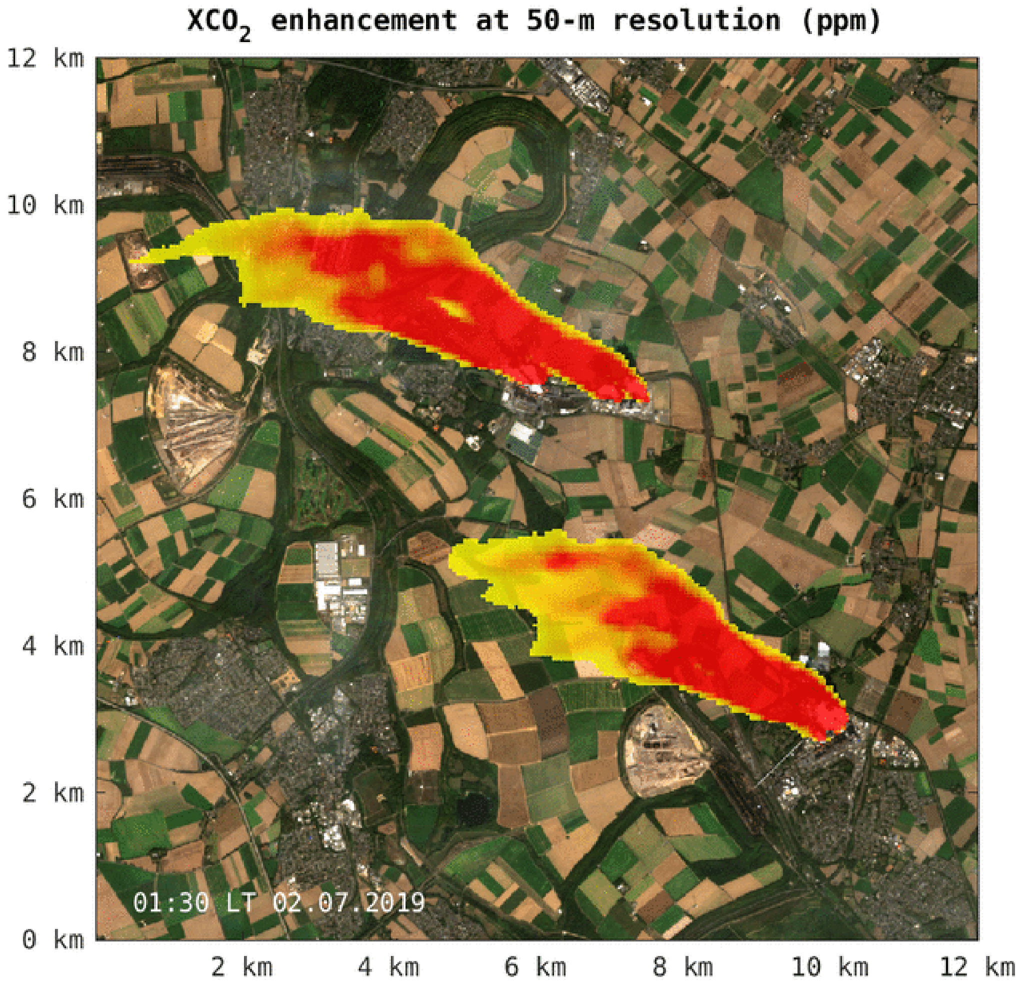
An example for power plants near Cologne

Emissions are divided over multiple stacks.

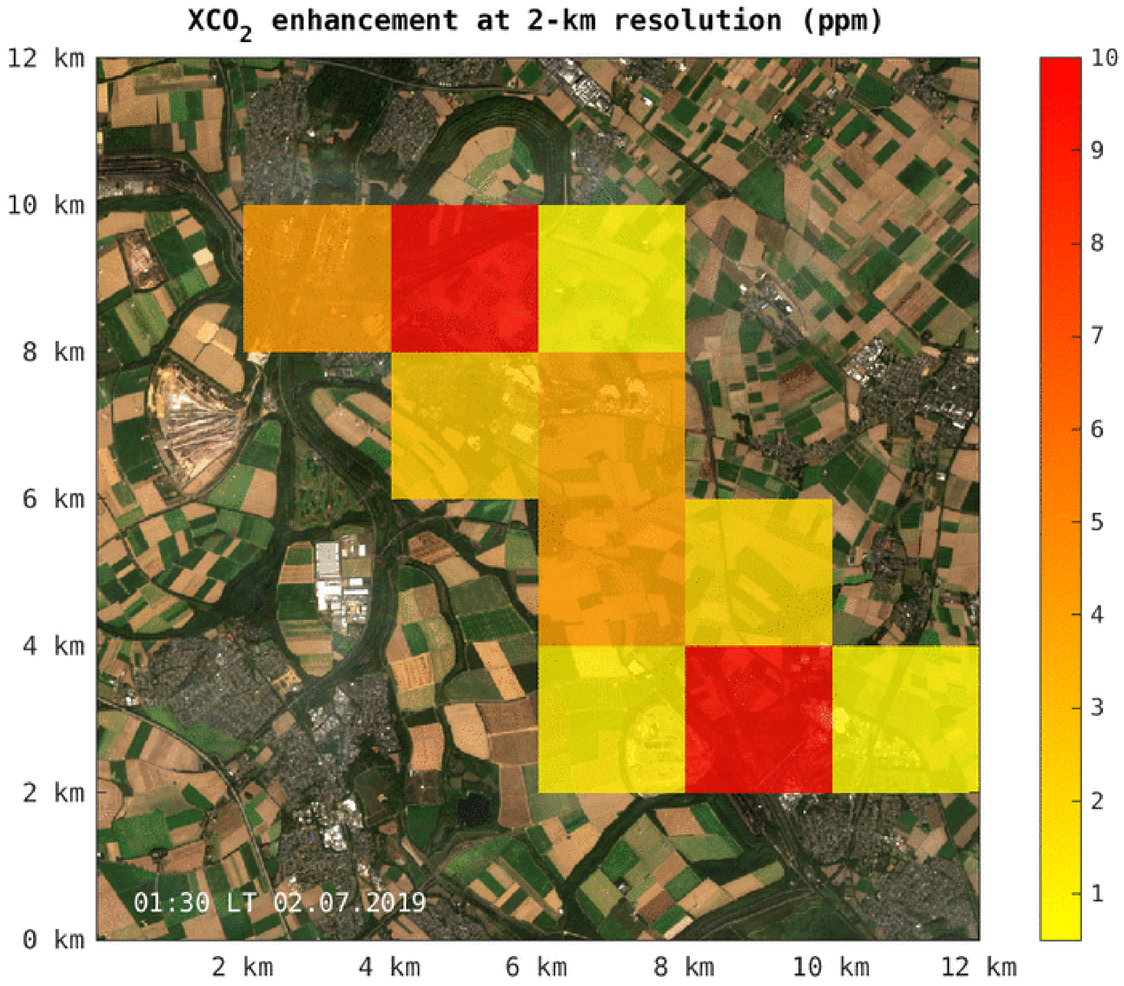


An example for power plants near Cologne

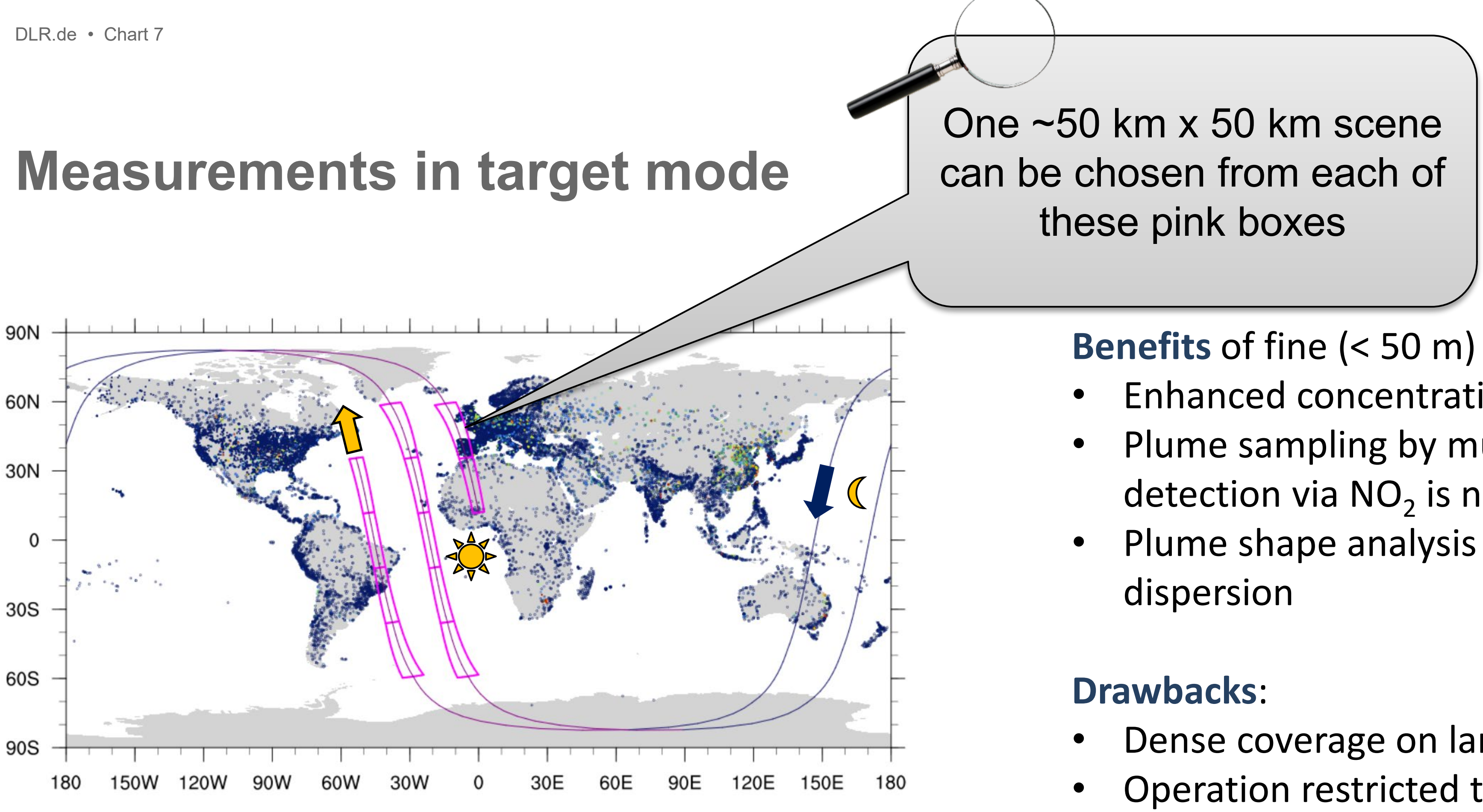
What CO2Image will see:



What CO2M will see:



Measurements in target mode



- Orbit altitude: 575 km
  → Inclination = 97.6618°
  → Orbital period T = 1.60033 h
  → Orbits per day = 14.9969
  → Velocity = 7.57304 km/s
- Agility = ± 25°
  - along track
  - across track
- Integration time = 89 ms
- ≈ 5 targets per branch between 60°S & 60°N
  → time for repositioning

Benefits of fine (< 50 m) ground resolution:

- Enhanced concentration contrast
- Plume sampling by multiple ground pixels (plume detection via NO_2 is not required)
- Plume shape analysis for constraining turbulent dispersion

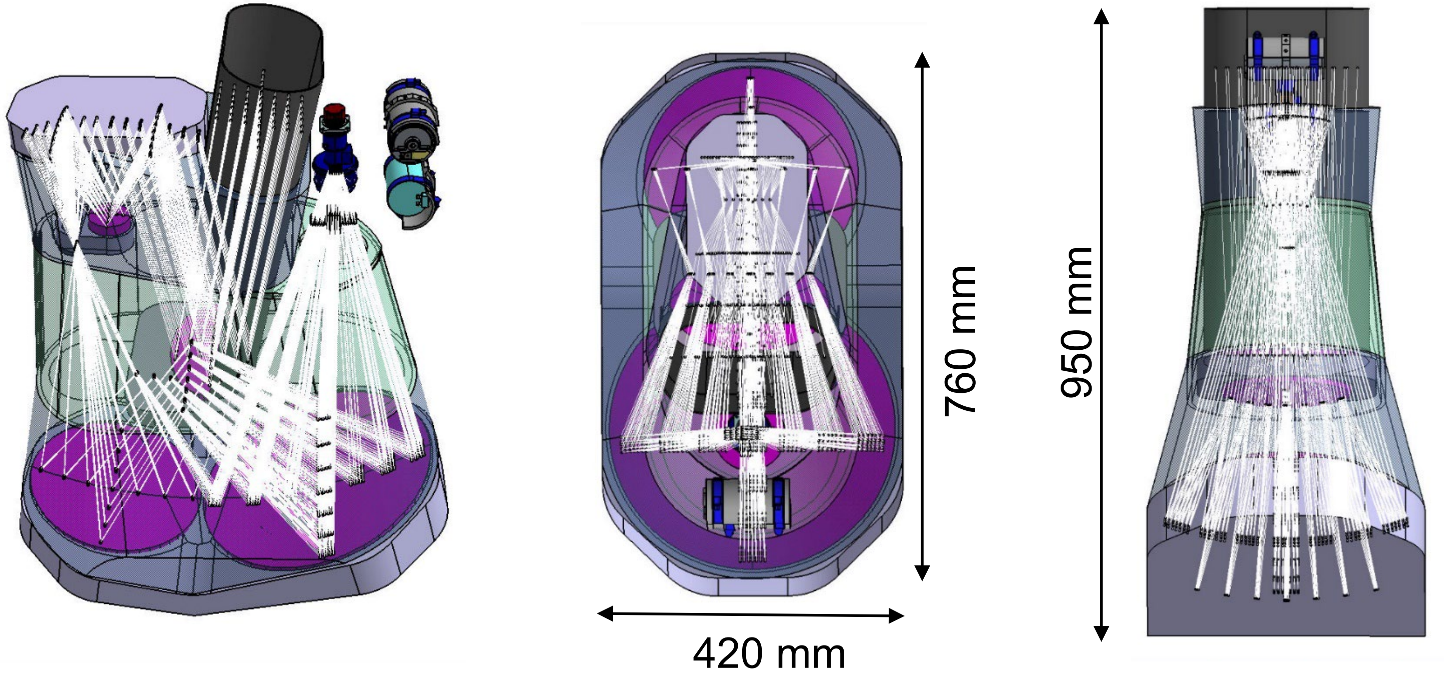
Drawbacks:

- Dense coverage on larger scales is not possible
- Operation restricted to “target mode”, focusing on a few 50 km x 50 km scenes per orbit

Thus: conceived of as a “magnifying glass” to **complement measurements from CO2M** and other survey missions.

COSIS Instrument description

Mass	90 kg
Swath	50 km
Spatial resolution	50 m x 50 m
Spectral range	1982-2092 nm
FWHM (2.5 pix)	1.29 nm
Resolving power	1600
Aperture diameter	15.0 cm
f number	2.4
Optical efficiency (η)	0.48
Integration time	70 ms
Detector pixel area	900 μm^2
Quantum efficiency (Qe)	0.8 e^- $photon^{-1}$
Dark current	1.6 fA pix^{-1} s^{-1}
Readout noise	100 e^-
Quantization noise	40 e^-

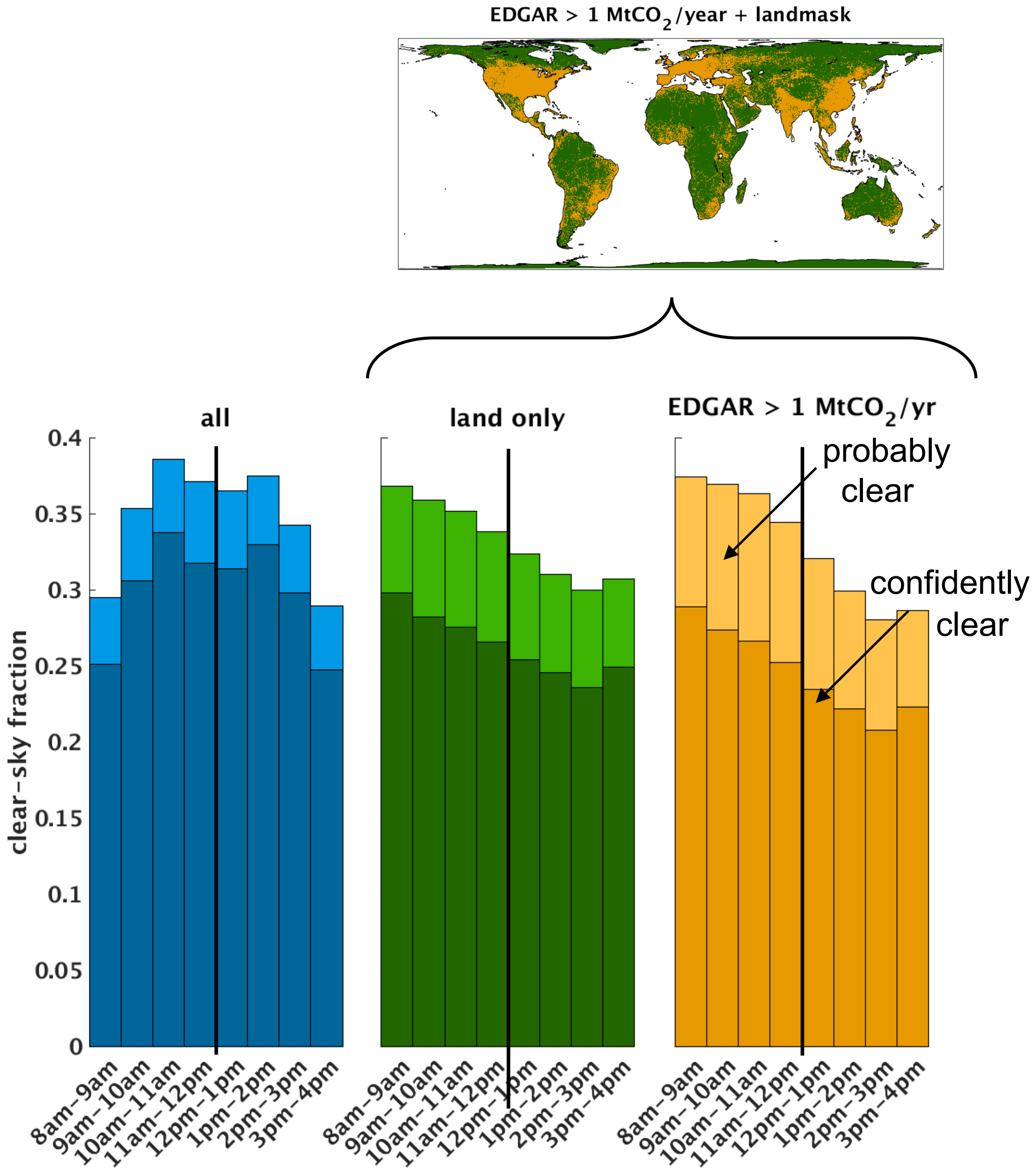


- Measurement in SWIR-2 channel
- Spectral resolution optimized to maximize signal while minimizing correlations with surface spectral reflectance (see Wilzewski et al., AMT, 2020)
- Fast optics, large telescope, forward motion compensation

DLR

Overpass time

- A mid-morning overpass time of 10:30 is planned
- The morning is advantageous in terms of:
    - Less cloud cover
    - (slightly) lower mean winds
    - Sufficient light

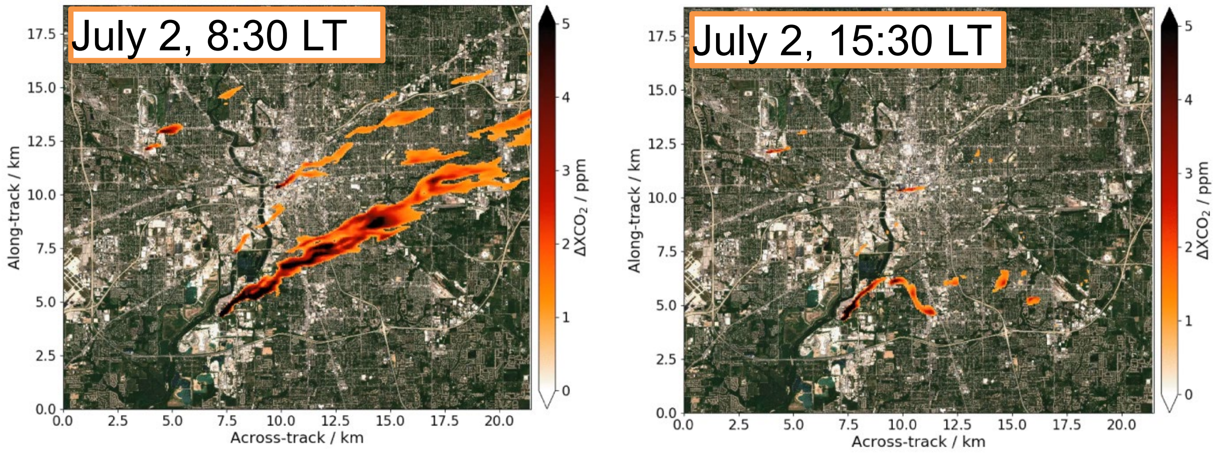


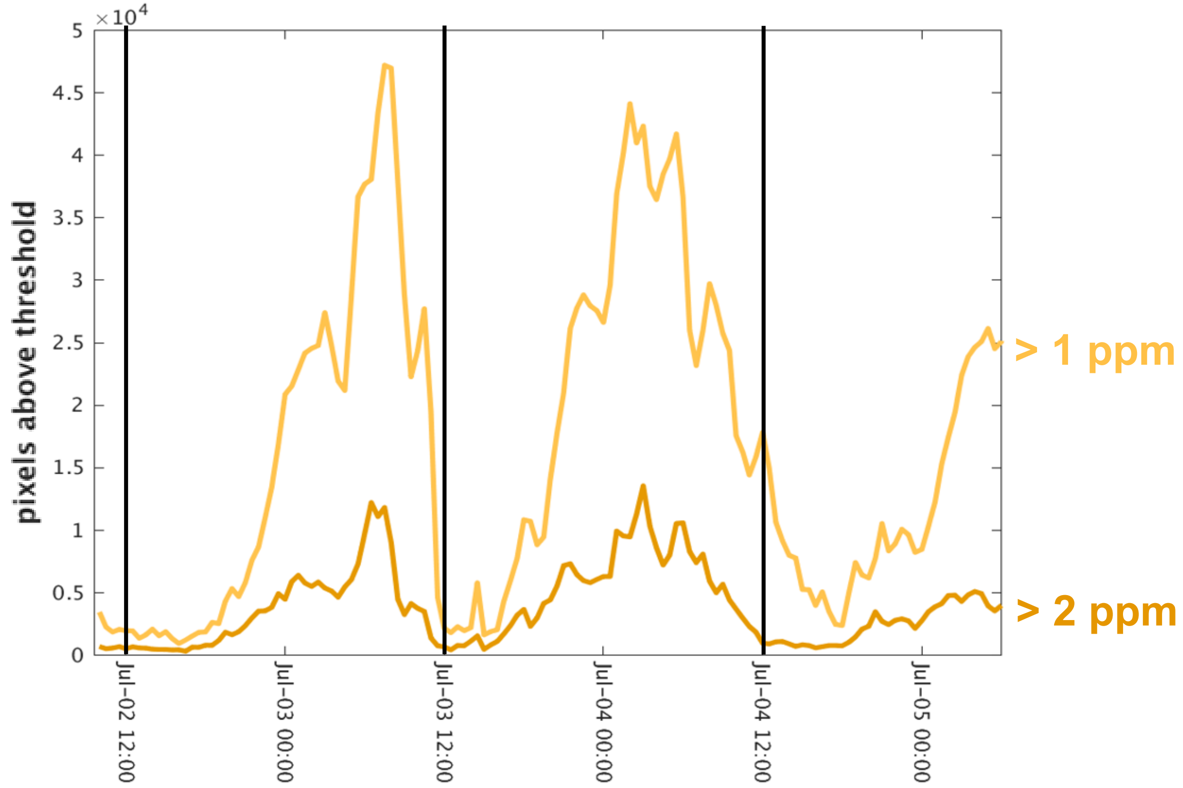
Marshall et al., in prep.

Overpass time

- A mid-morning overpass time of 10:30 is planned
- The morning is advantageous in terms of:
    - Less cloud cover
    - (slightly) lower mean winds
    - Sufficient light
    - Less turbulence → larger signals

True for turbulent scenes on the scale of 10s of meters – at the kilometer scale this is less critical!

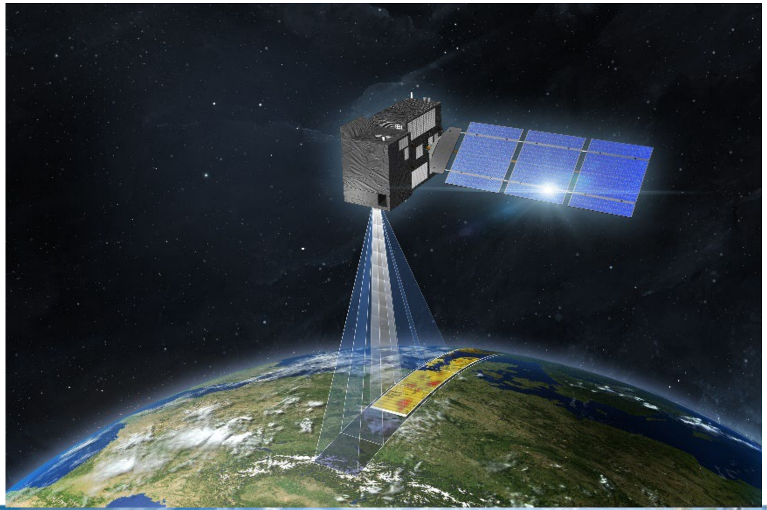




Marshall et al., in prep.

Conclusions

- CO2Image will provide high-resolution measurements of XCO_2 to quantify emissions from point sources > 1 $MtCO_2$/yr, and detect smaller sources (> 0.3 $MtCO_2$/yr)
- Complementary to global survey missions such as CO2M
- Public mission providing public, transparent data
- Planned launch in 2026
- (we can also measure methane)



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