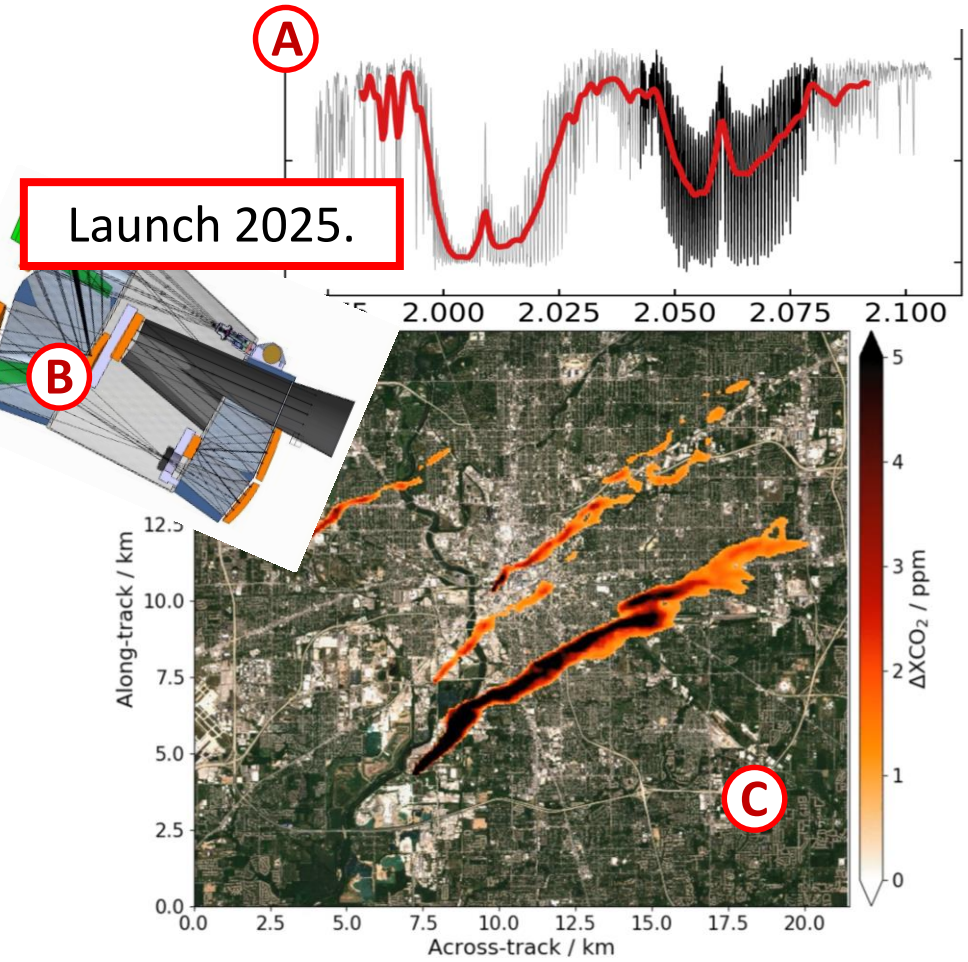
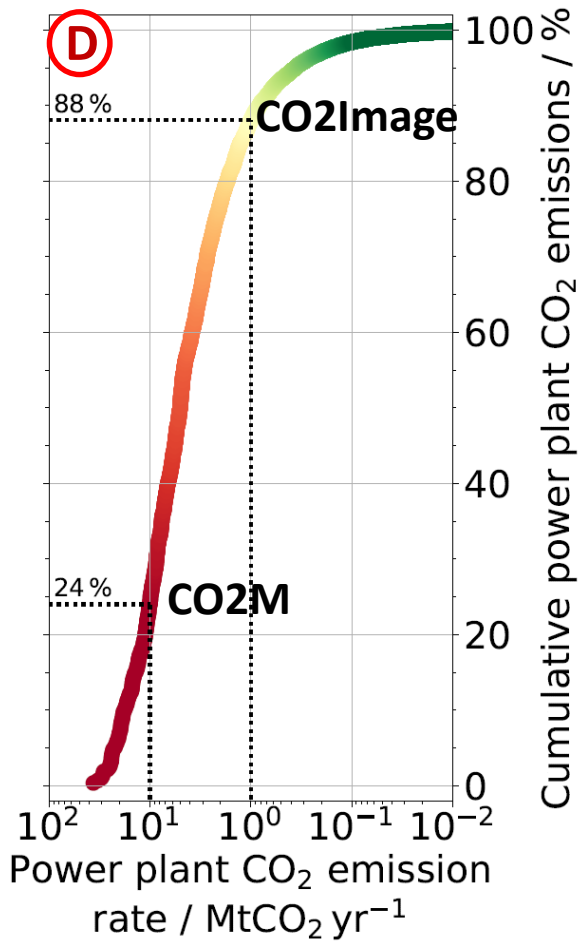
Zooming in on localized CO_2 emissions from space: the CO2Image demonstrator

André Butz et al. (see last slide for all co-authors)



CO2Image aims at reliable emission quantification for localized sources down to 1 $MtCO_2/y$ (~90% of all coal-fired power plant emissions), enabled by fine ground resolution (50 m):

- Zoom-in companion for CO2M and other survey missions.
- SWIR-2 spectrometer with 1-1.5 nm spectral resolution to disentangle surface spectral features.
- Payload fits on DLR-CompactSat.



Wilzewski et al., https://doi.org/10.5194/amt-13-731-2020, AMT, 2020;
Strandgren et al., https://doi.org/10.5194/amt-13-2887-2020, AMT, 2020

CO2Image: CO_2 point-source quantification > 1MtCO_2/y

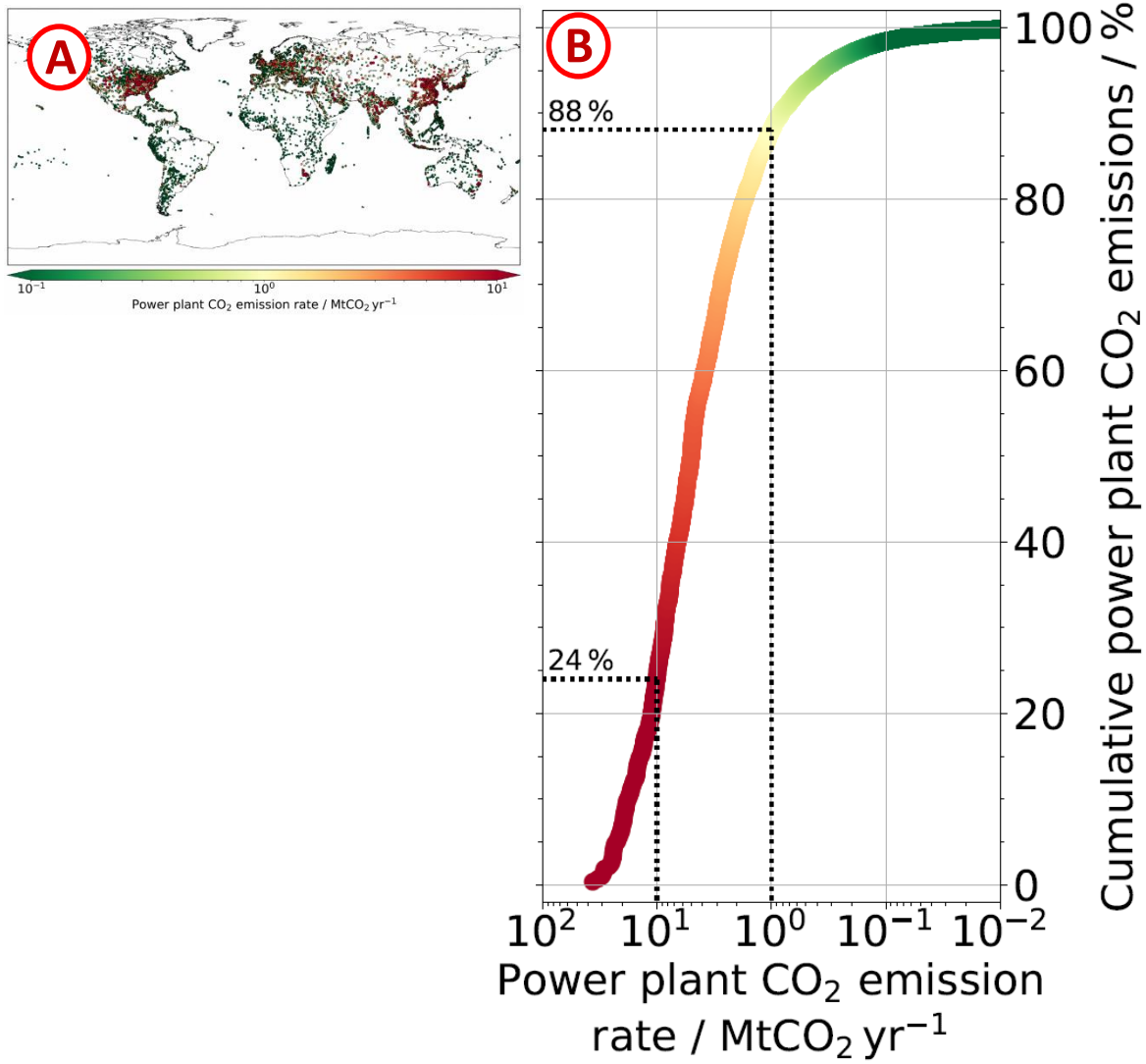
Launch 2025.

CO2Image: reliable emission quantification for localized sources down to 1 MtCO_2/y

Global survey missions (OCO-2, CO2M) with **ground resolutions on the km-scale** can resolve point-source emissions >10 MtCO_2/y i.e. **up to 25% of emissions** from global coal power-plants.

Missions with **extremely fine ground-resolution (<50m)** are able to detect and quantify point-source emissions >1 MtCO_2/y i.e. **up to 90% of emissions** from global coal power plants.

The world's coal-fired powerplants



Strandgren et al., https://doi.org/10.5194/amt-13-2887-2020, AMT, 2020

CO2Image: Zoom-in companion for CO2M et al.

Extremely fine ground-resolution (<50m) facilitates:

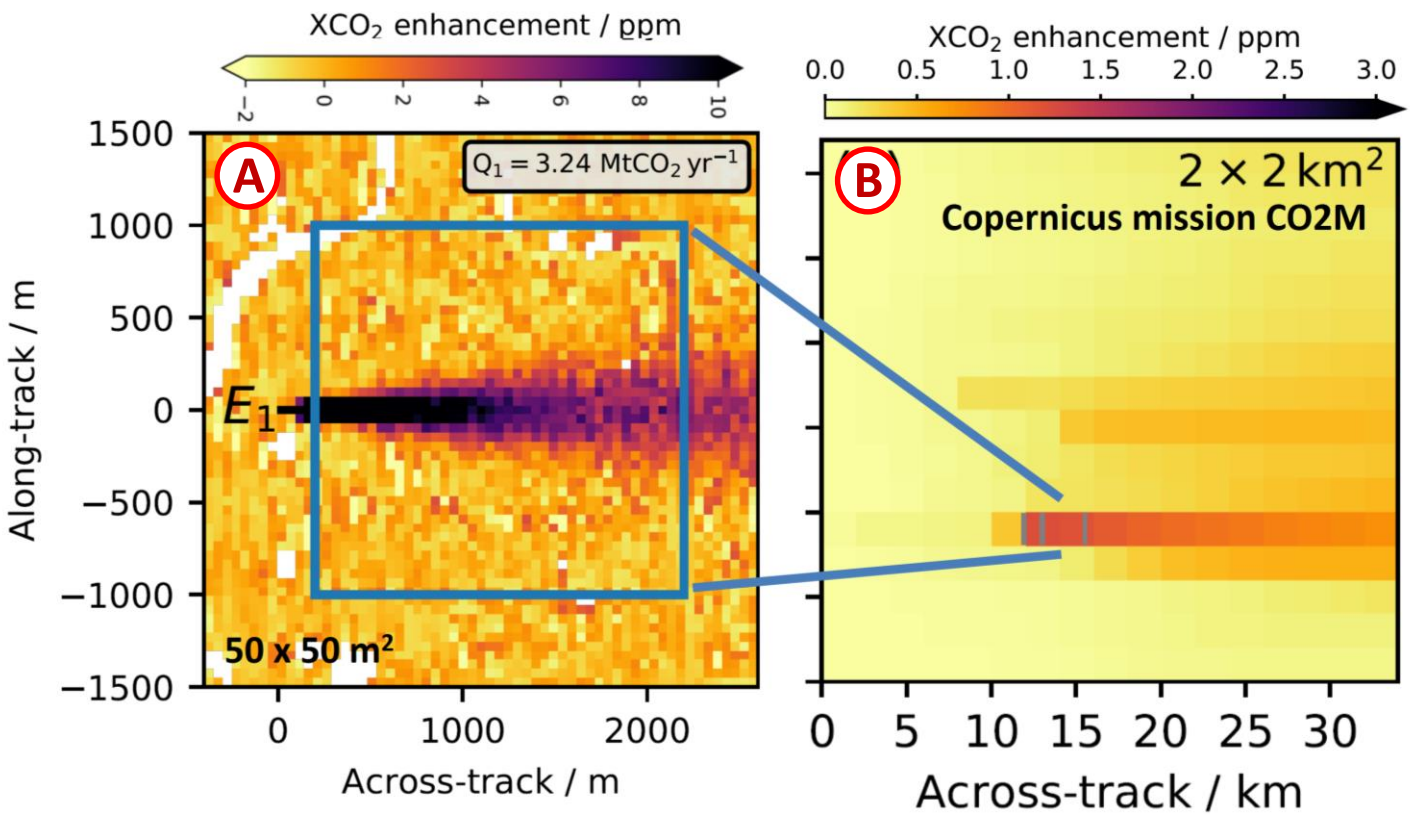
- Enhanced **concentration contrast**.
- **Plume sampling** by multiple ground pixels.
- **Plume shape** analysis for constraining turbulent dispersion.

... but, it hinders:

- dense coverage on larger scales and thus, it is not suitable for regional-to-continental scale assessments.

Thus, CO2Image will be a **„zoom-in“ companion for CO2M** and other survey missions.

Simulated plume of a 3.24 $MtCO_2$/y source on CO2Image and CO2M resolution



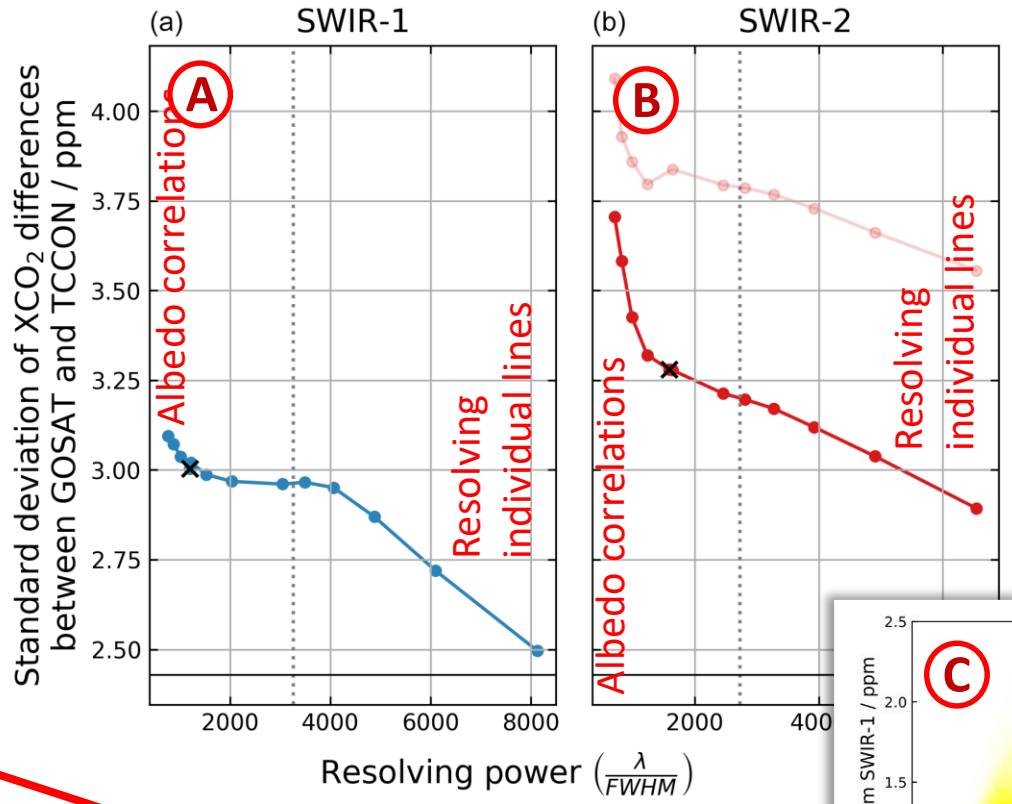
Strandgren et al., https://doi.org/10.5194/amt-13-2887-2020, AMT, 2020

CO2Image: SWIR-2 with 1 - 1.5 nm resolution

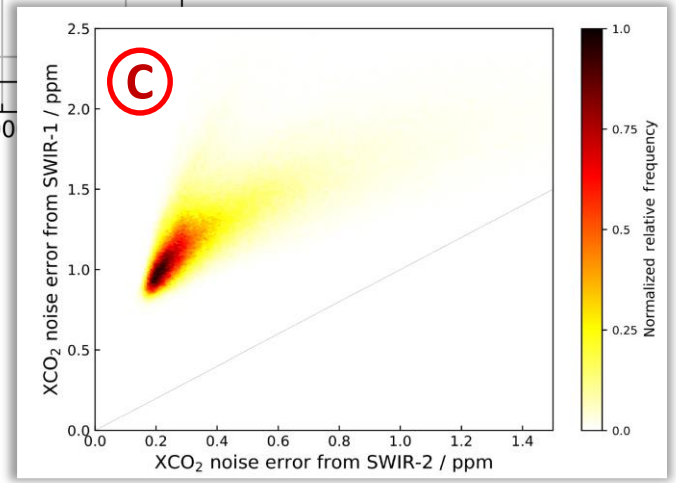
Extremely fine ground-resolution (<50m) requires collecting photons and CO_2 absorption signal in the spectral domain - **coarser but not too coarse spectral resolution**:

- **Prefer SWIR-2 (2 micron) over SWIR-1 (1.6 micron)** since SWIR-1 too noisy due to smaller CO_2 absorption optical depth (even if accounting for typically higher albedo).
- **„Optimal“ resolving power ~1500 (1-1.5 nm at 2 micron).** Smaller resolving power implies (unresolvable) **correlations with surface spectral reflectance**.

Retrieval error as a function of spectral resolution (derived from degradation of GOSAT spectra)



Retrieval noise error for SWIR-1 and SWIR-2



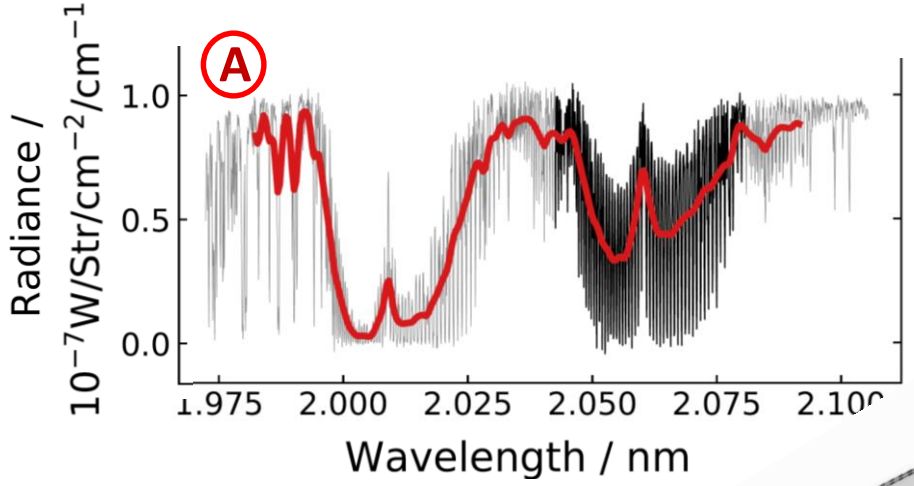
See poster by J. Wilzewski, same session.

Wilzewski et al., https://doi.org/10.5194/amt-13-731-2020, AMT, 2020;

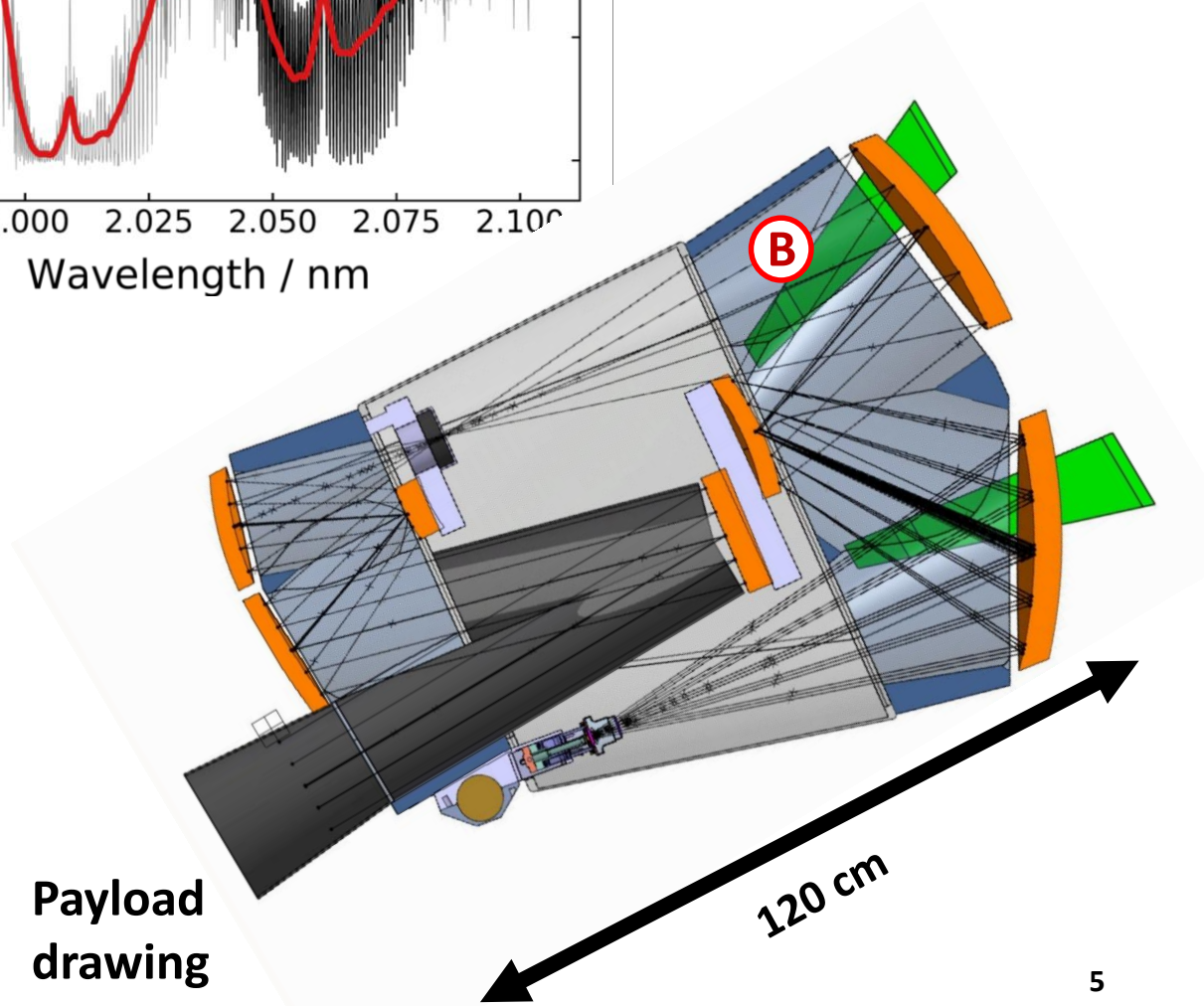
CO2Image: Preliminary instrument fits on compact satellite

Extremely fine ground-resolution (<50m) requires relative **large telescope, fast optics, forward motion compensation**: preliminary instrument concept fits an DLR Compact-Sat.

Orbit	600 km, sun-synchronous
Mass	90 kg
Swath	50 km
Spatial resolution	$50 \times 50\,\mathrm{m}^2$
Spectral range	1559–1672 or 1982–2092 nm
FWHM (2.5 pix)	1.37 or 1.29 nm
Resolving power	1200 or 1600 (–)
Aperture diameter	15.0 cm
f number (f_{num})	2.4 (–)
Optical efficiency (η)	0.48 (–)
Integration time (t_{int})	70 ms
Detector pixel area (A_{det})	$900\,\mu\mathrm{m}^2$
Quantum efficiency (Q_{e})	$0.8\,\mathrm{e}^-\,\mathrm{photon}^{-1}$
Dark current (I_{dc})	$1.6\,\mathrm{fA\,pix}^{-1}\,\mathrm{s}^{-1}$
Readout noise	$100\,\mathrm{e}^-$
Quantization noise	$40\,\mathrm{e}^-$



Spectral measurement

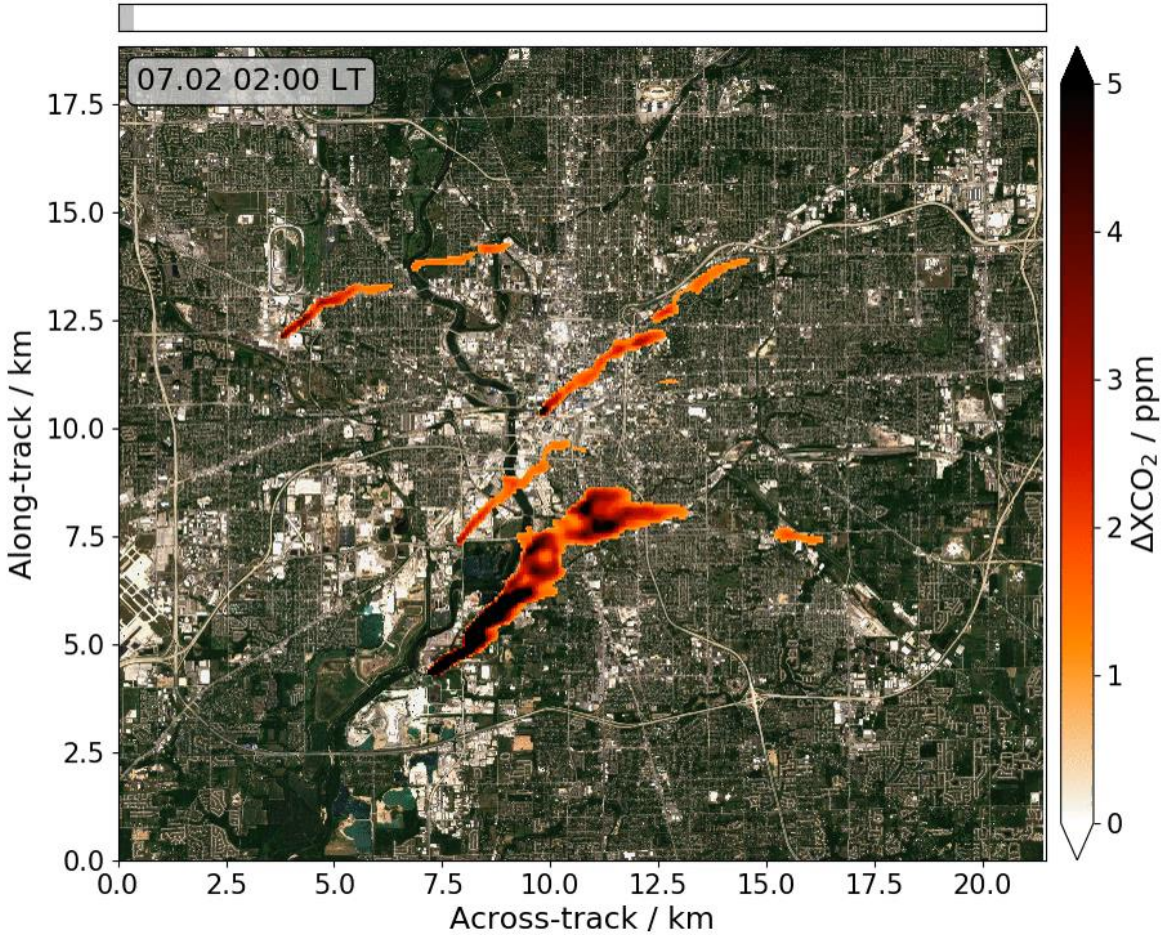


Payload drawing

Wilzewski et al., https://doi.org/10.5194/amt-13-731-2020, AMT, 2020;
Strandgren et al., https://doi.org/10.5194/amt-13-2887-2020, AMT, 2020

CO2Image: Plume detection, emission quantification

Ongoing: Plume detection via image processing. Emission quantification via mass balance, continuity considerations and emerging techniques.



LES simulation for Indianapolis CO_2 sources with 50m ground resolution [emission from HESTIA @ K. Gurney, surface reflectance from Sentinel-2]

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