Universität Bremen

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Institute of Environmental Physics

Influence of a stray light correction on airborne imaging remote sensing data for greenhouse gas observations with MAMAP2D-Light

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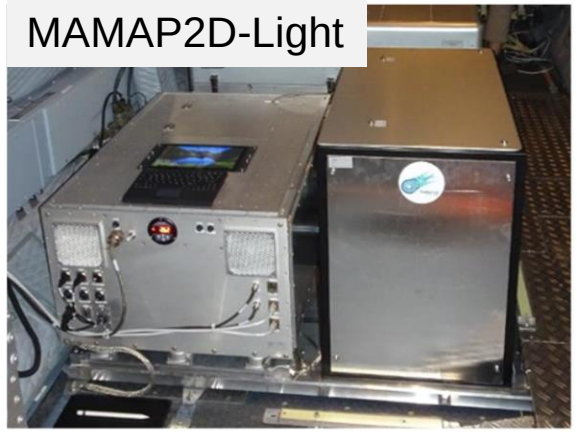
Bologna 04.07.2024

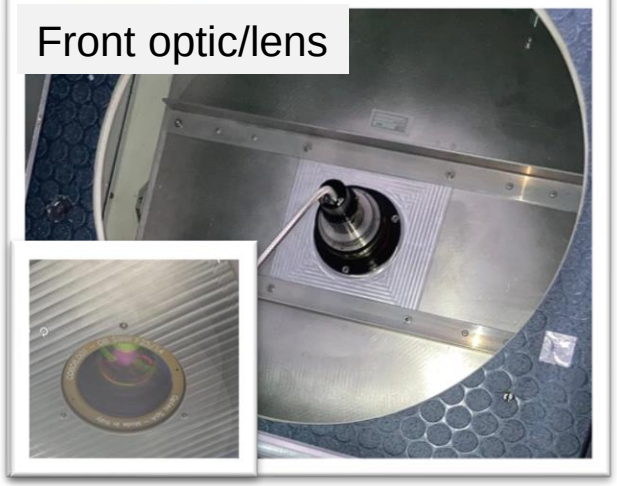
Airborne remote sensing

MAMAP2D-Light deployed during CoMet 2.0 Arctic mission in Canada in 2022

MAMAP2D-Light



Front optic/lens



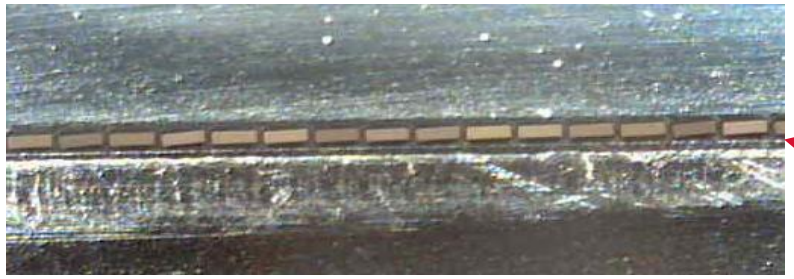
DLR

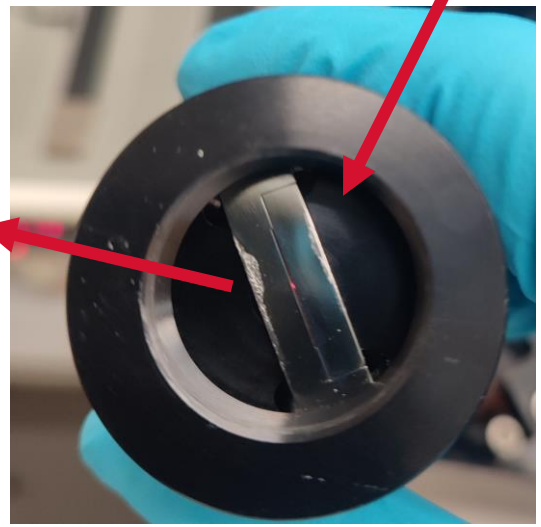
CoMet 2.0 ARCTIC

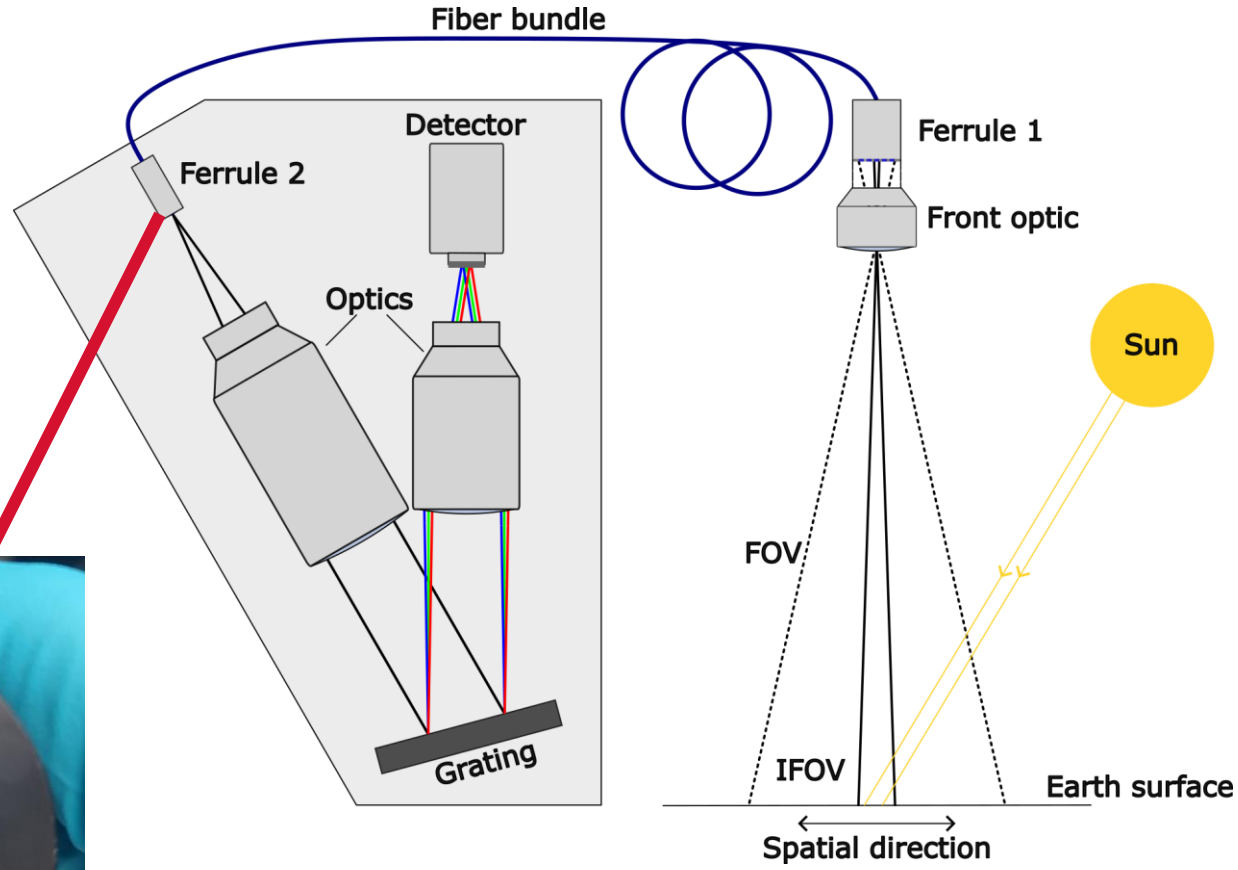
MAMAP2D-Light

Methane **A**irborne **MAP**per **2D**-**Light**

- Passive remote sensing imaging grating spectrometer
- ~1 nm spectral resolution, from 1550 – 1690 nm
- 28 spatial pixels
- 50x50 m² to 150x150 m² pixel size dependent on flight altitude



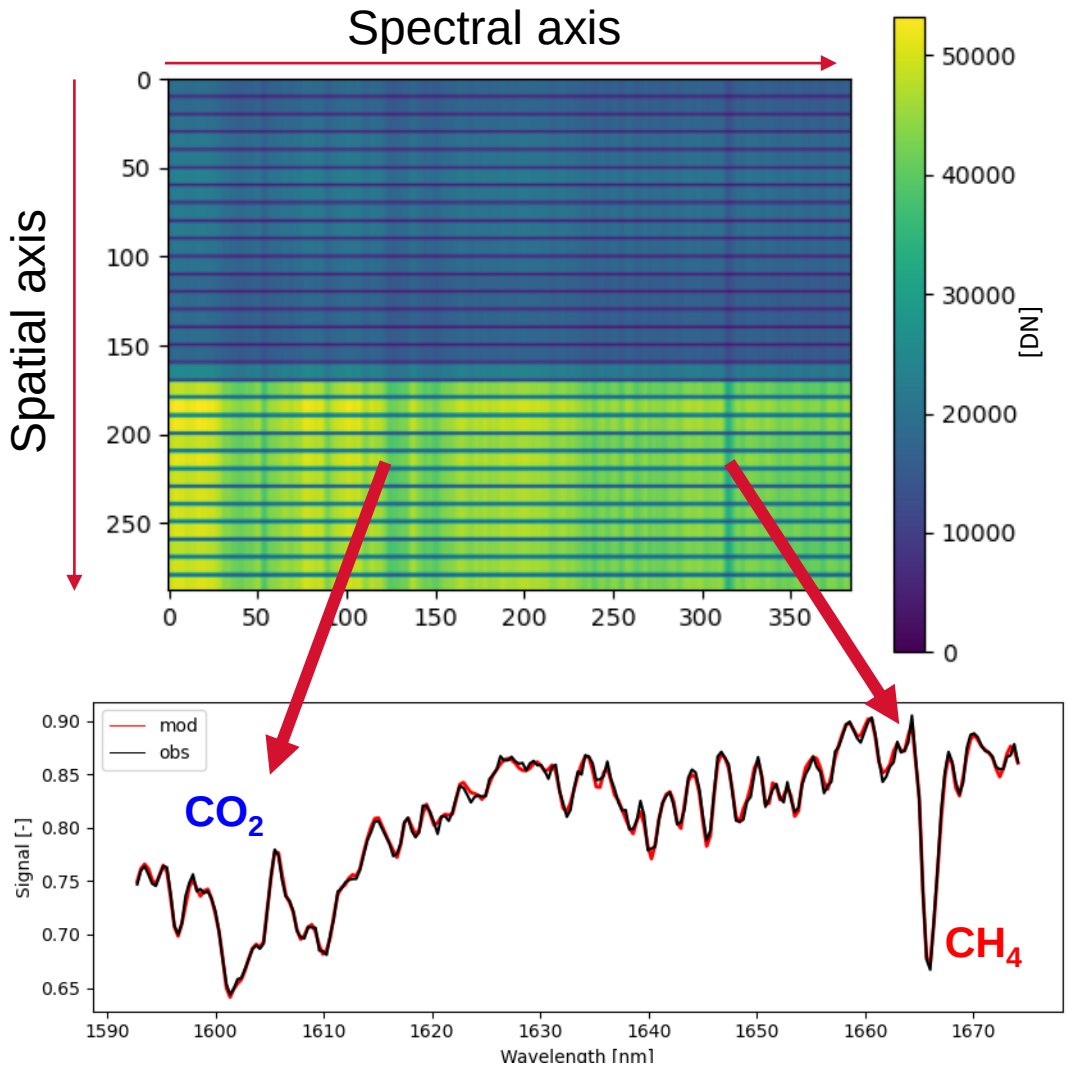




Retrieving greenhouse gas anomalies

- **W**eighting **F**unction **M**odified **D**ifferential **O**ptical **A**bsorption **S**pectroscopy (WFM-DOAS, Krings et. al. 2011)
  - A radiative transfer model is fitted at measured spectra to retrieve CO_2 and CH_4 column anomalies as **P**rofile **S**caling **F**actors (PSF)
  - Additive offset in WFM DOAS can not be fitted
  - E.g. stray light adds an offset to the measured spectra

- Proxy method is used to correct light-path-related and instrumental errors, for methane (Krings et. al. 2011)
  - $Proxy\_CH_{4_{PSF}} = \frac{CH_{4_{PSF}}}{CO_{2_{PSF}}}$



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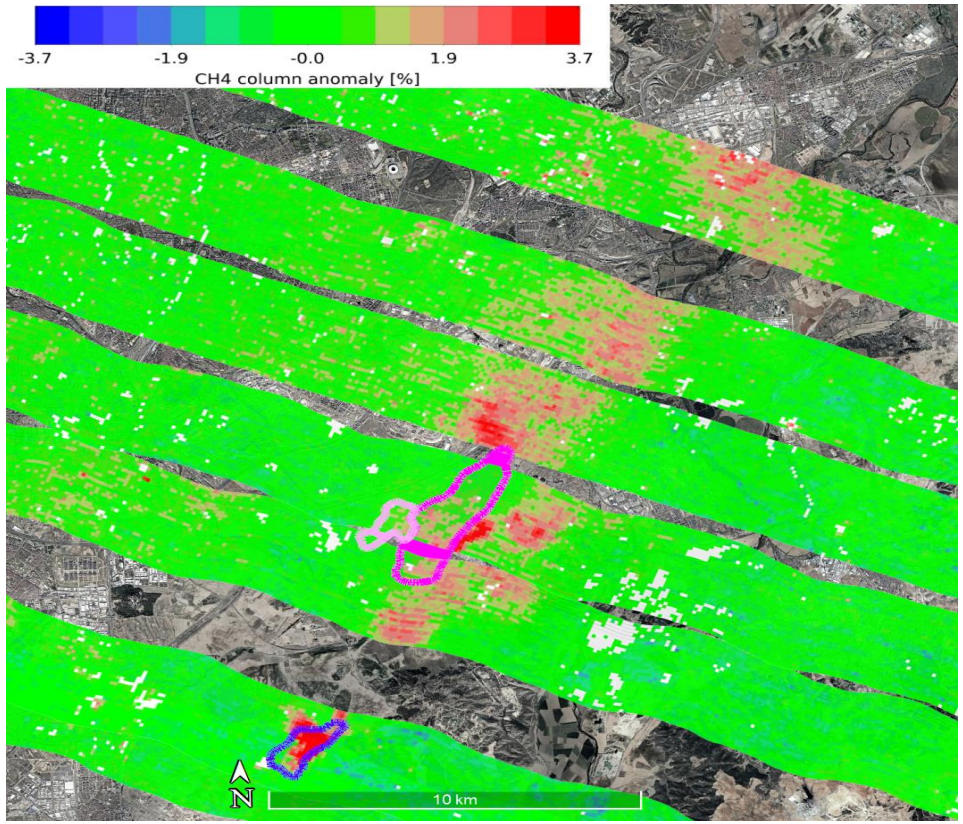
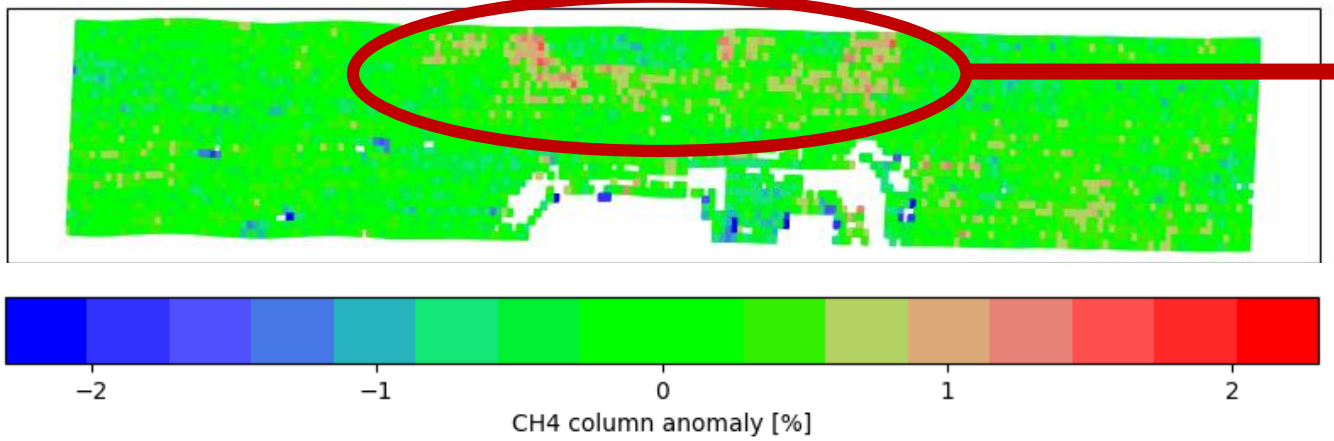


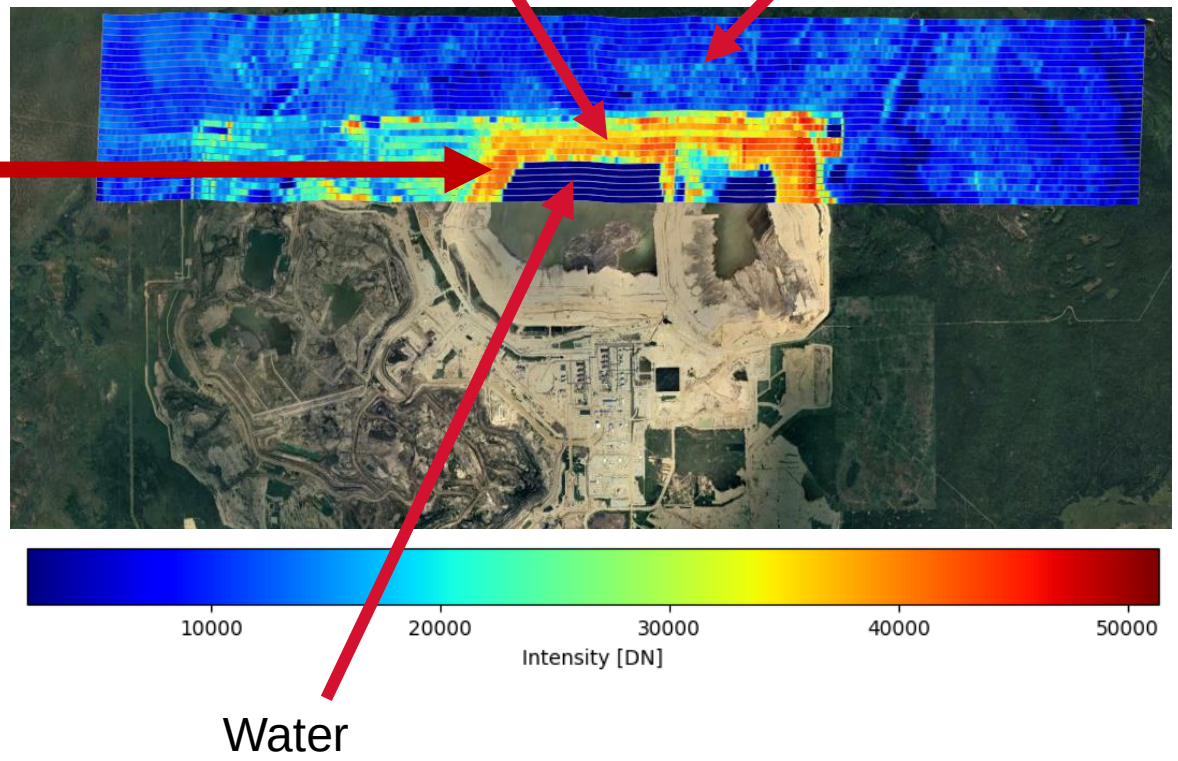
Artifact in MAMAP2D-Light data

CH_4 column anomaly in shape of area with increased intensity



Oil sand

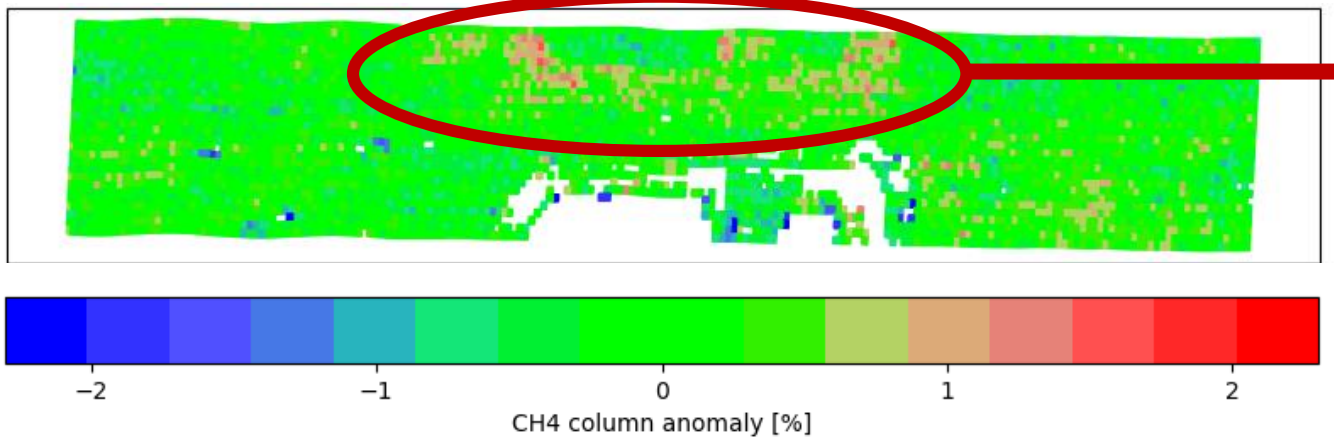
Vegetation

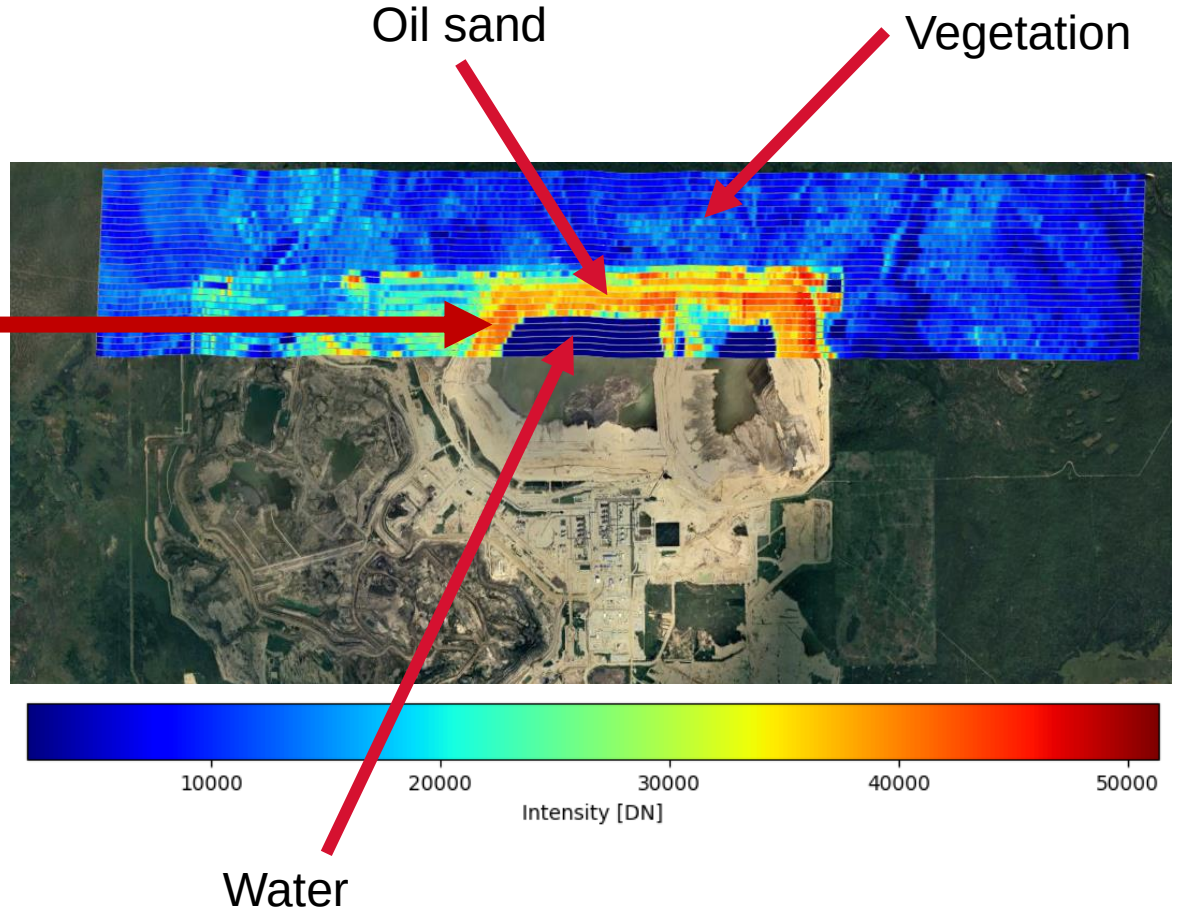


Water

Artifact in MAMAP2D-Light data

CH_4 column anomaly in shape of area with increased intensity

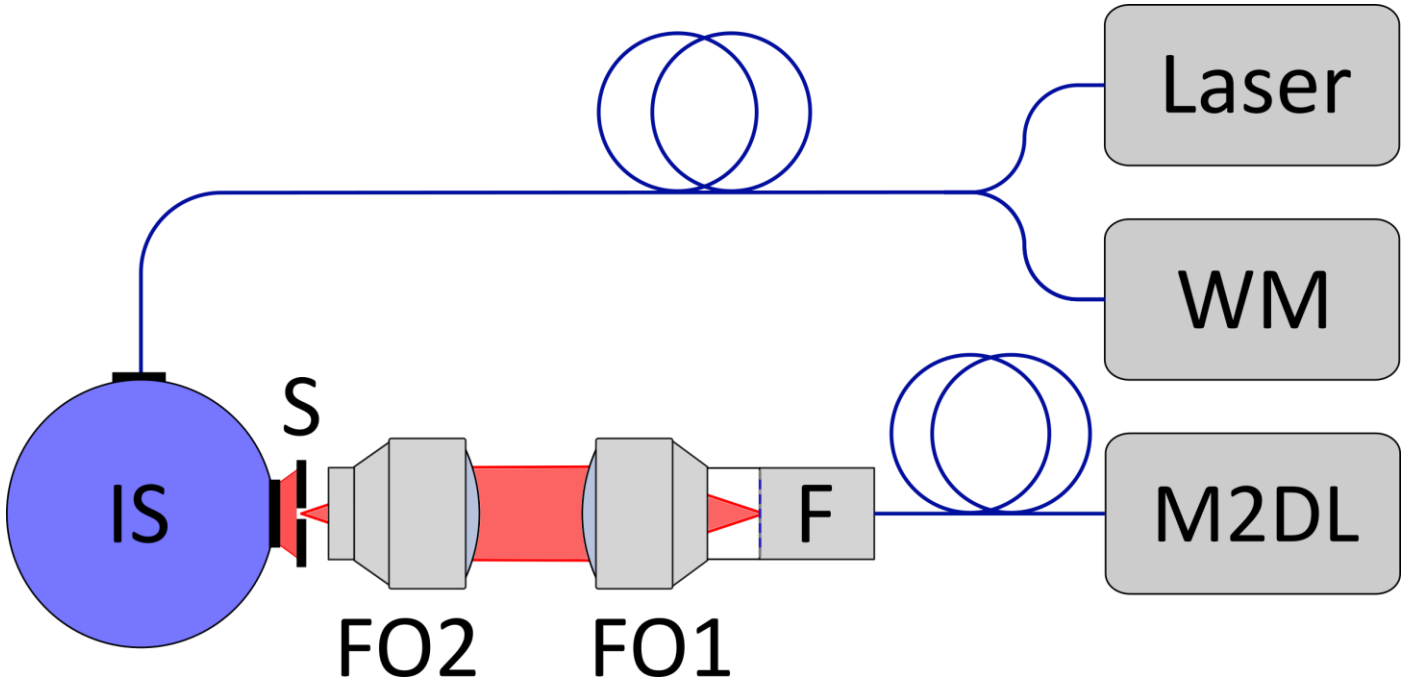




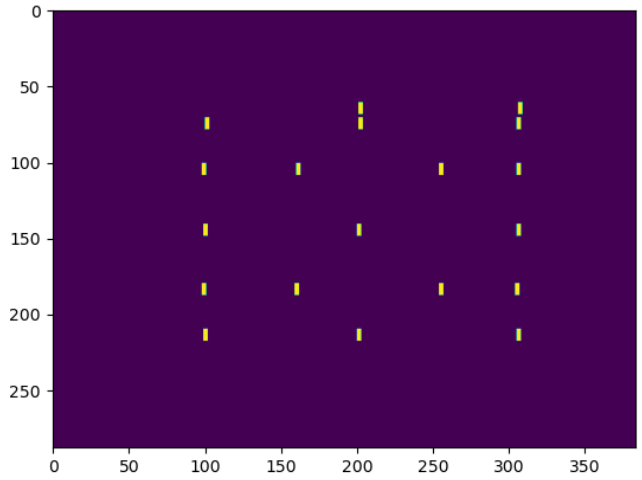
This could be caused by stray light, therefore stray light characterization measurements were performed

Stray light measurements

- Based on Tol et. al. 2018 “Characterization and correction of stray light in TROPOMI-SWIR”
- Tunable Laser, observed with a **W**ave-**M**eter, led into an integrating sphere. Adjustable slit (**S**) imaged via a second front optic (**FO**) at single fiber of the entrance ferrule of MAMAP2D-Light (M2DL)



Measured positions:

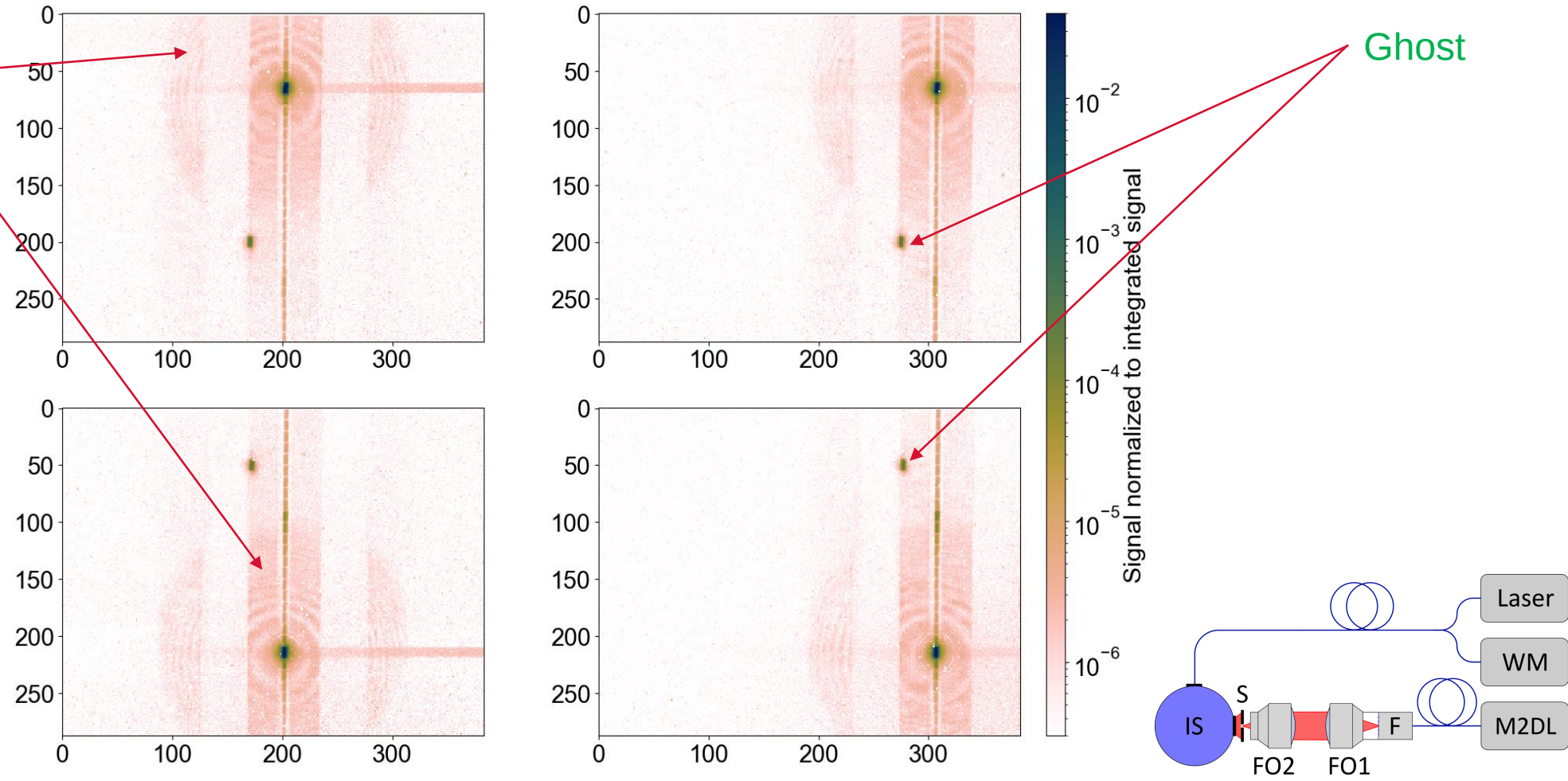


Stray light measurements

Approximately 4% stray light!

Stable stray light

Ghost



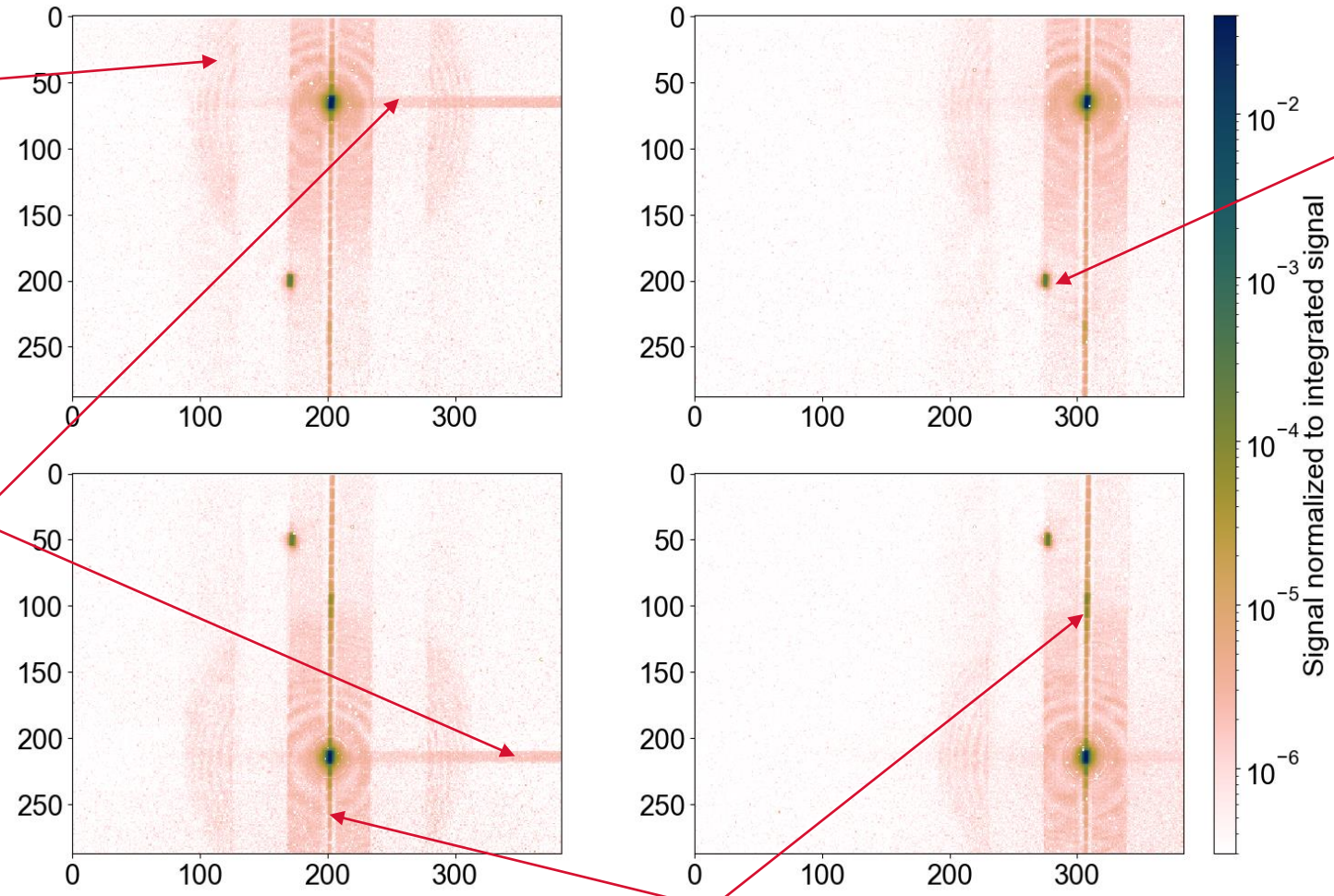
Stray light measurements

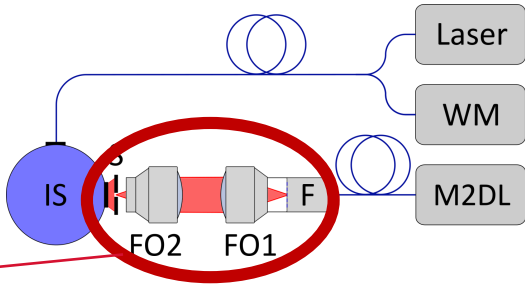
Approximately 4% stray light!

Stable stray light

Ghost

Insufficient side mode suppression of used Laser



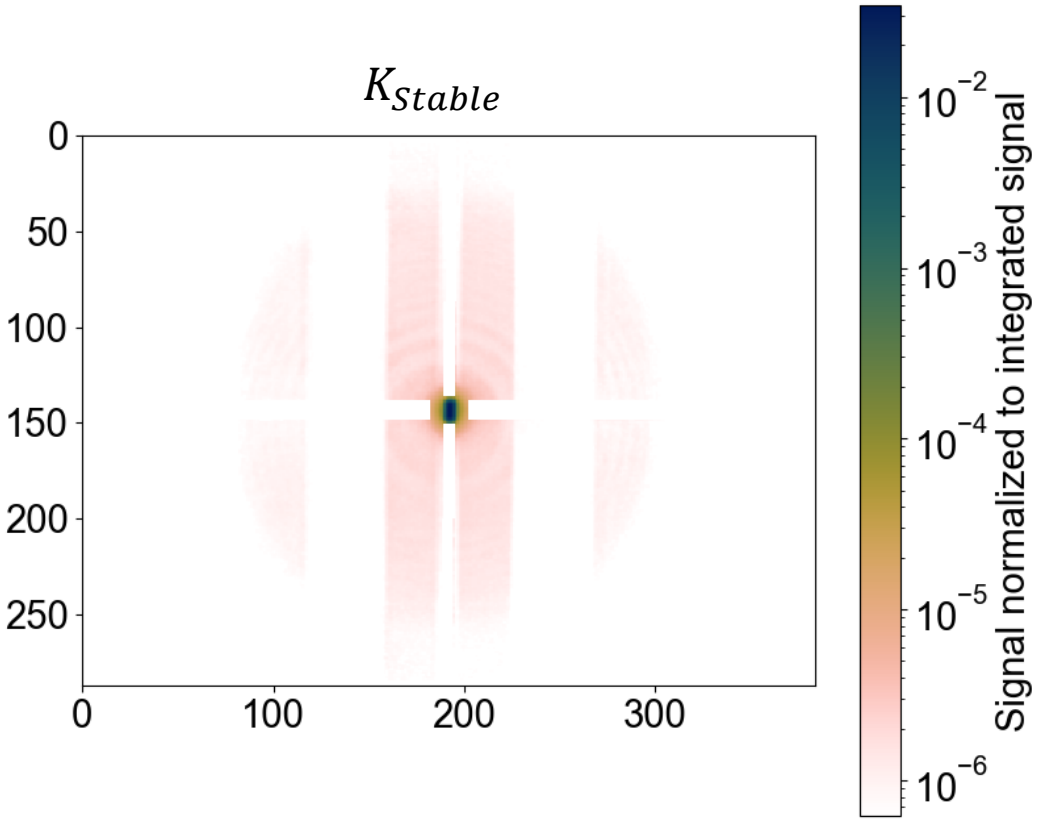


Insufficient stray light suppression from before the instrument

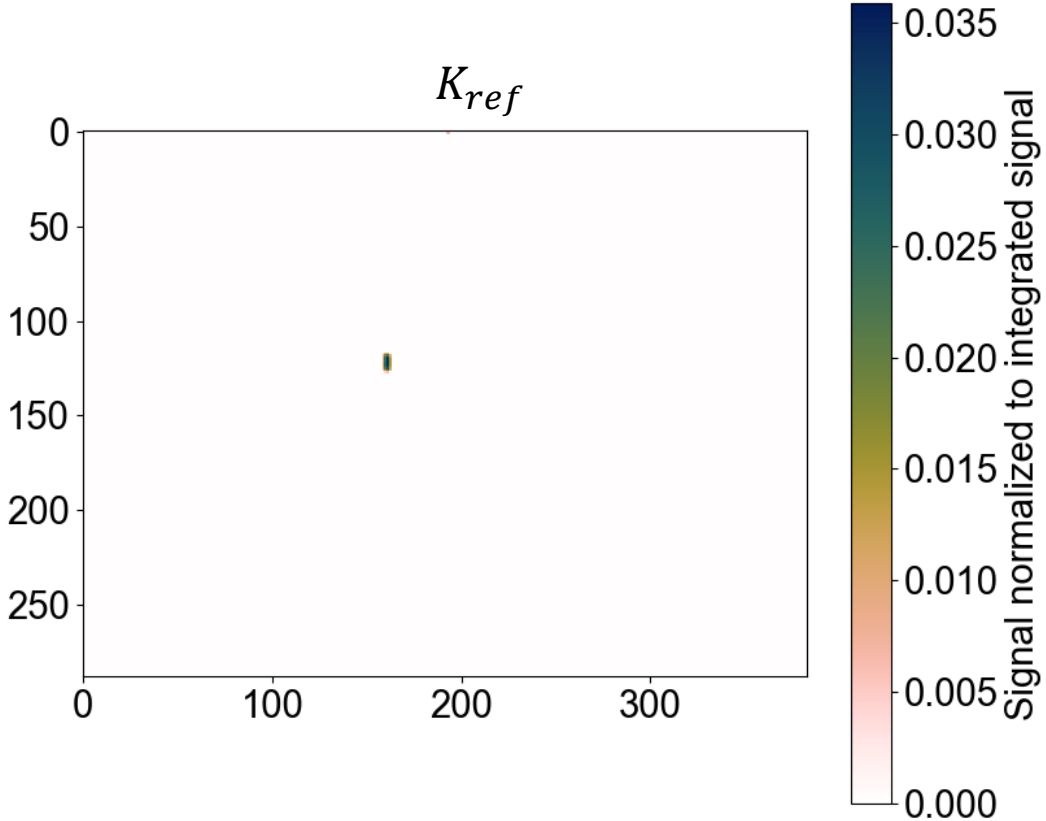
Stray light correction

Based on (Tol et al, 2018)

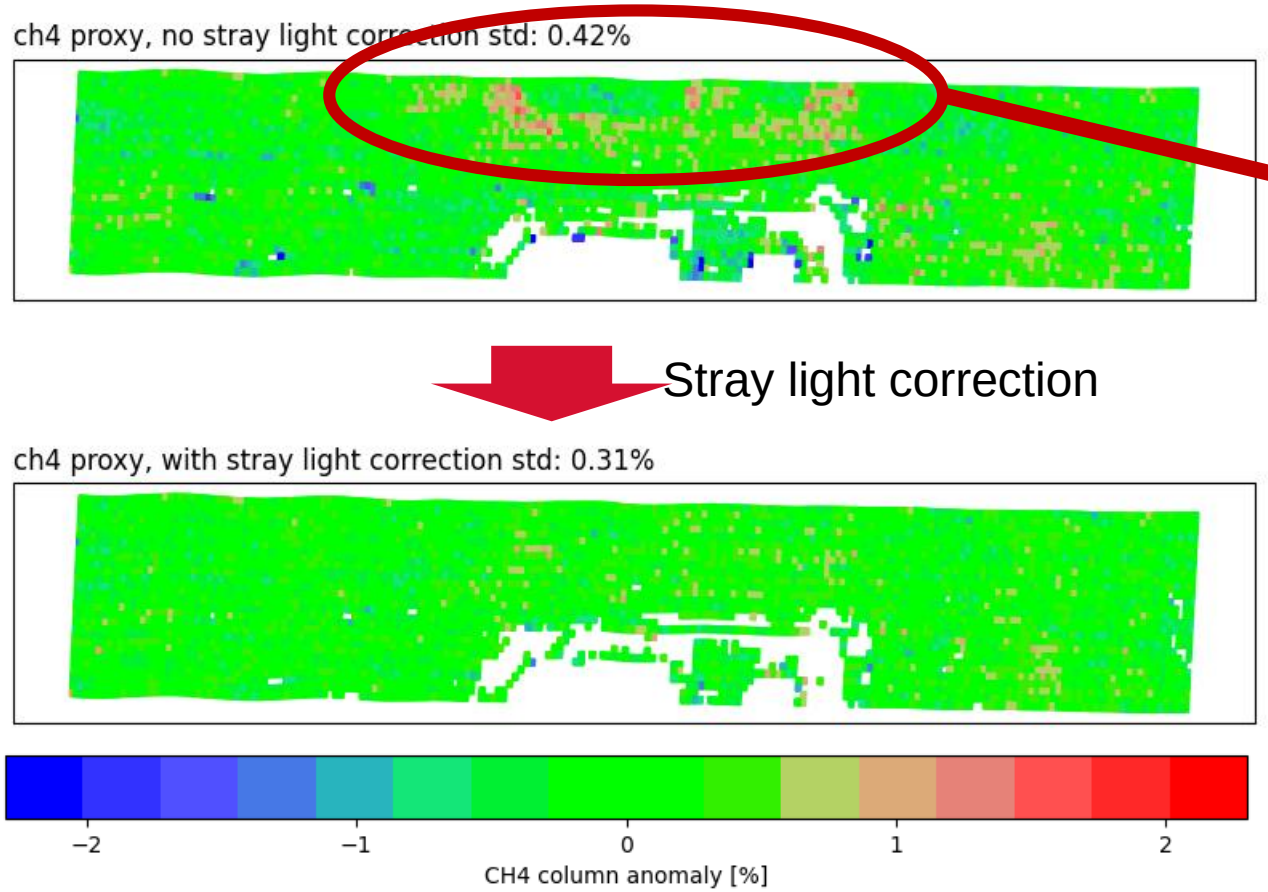
- Spatial and spectral invariant stray light K_{Stable}
  - Non-stray-light-related features are set to zero
    - Pure spectral stable stray light is not corrected

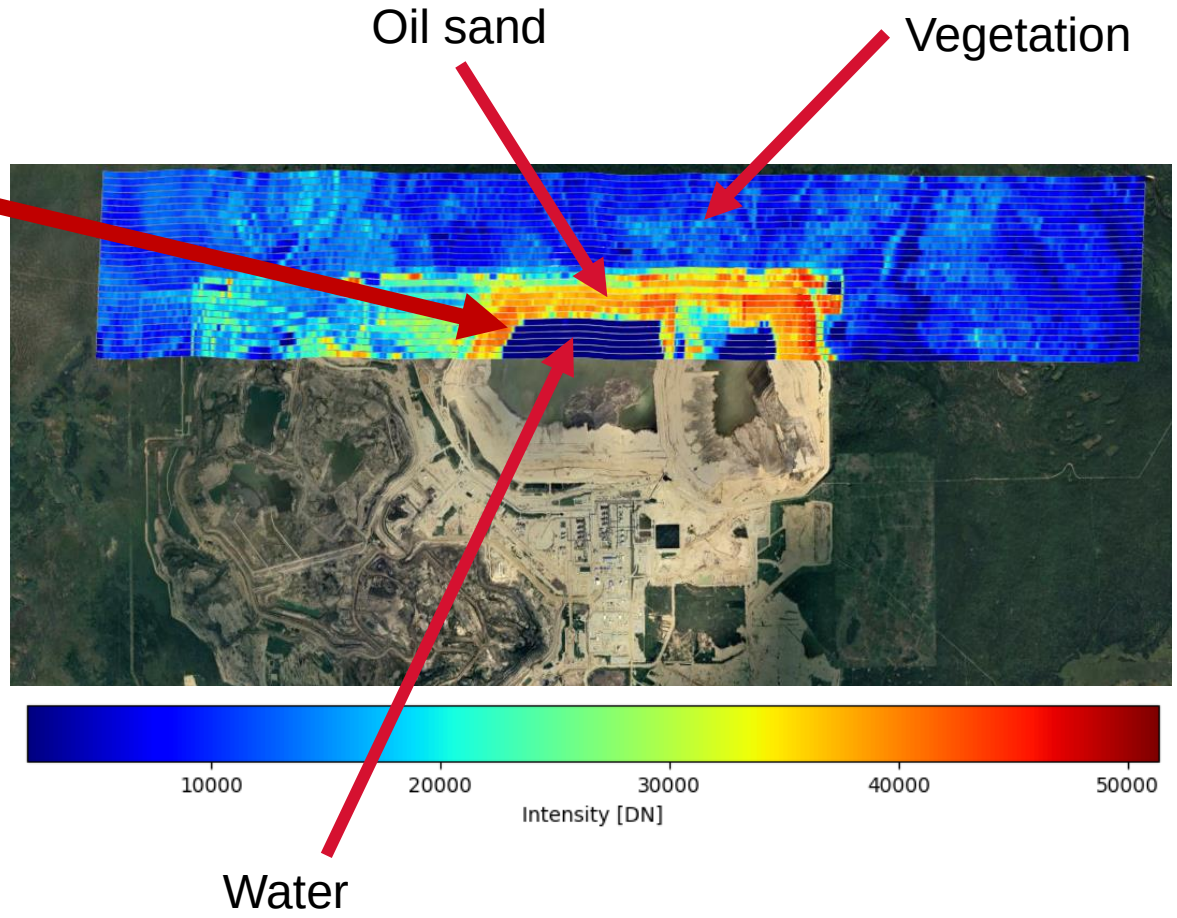


- Sharp reflection K_{ref} (Ghost)
  - Shifts the image of the ghost position



Artifact in MAMAP2D-Light data

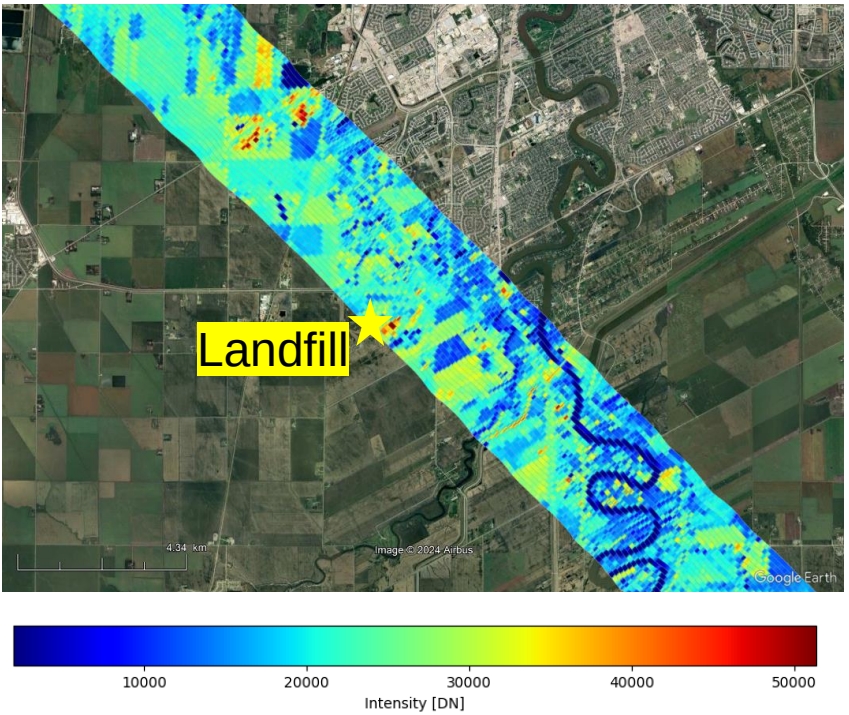




→ Stray light correction required for high contrast scenes

Proxy corrected data with stray light correction

Intensity variations of urban and agricultural surfaces:

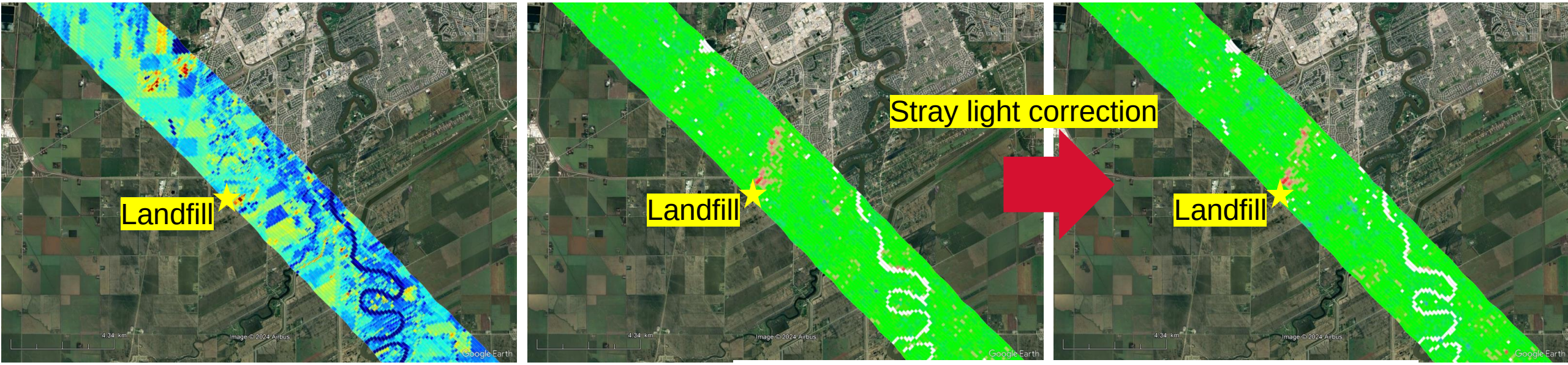


Proxy corrected data with stray light correction

Intensity variations of urban and agricultural surfaces:

Estimated methane flux: 12.8 kt/yr

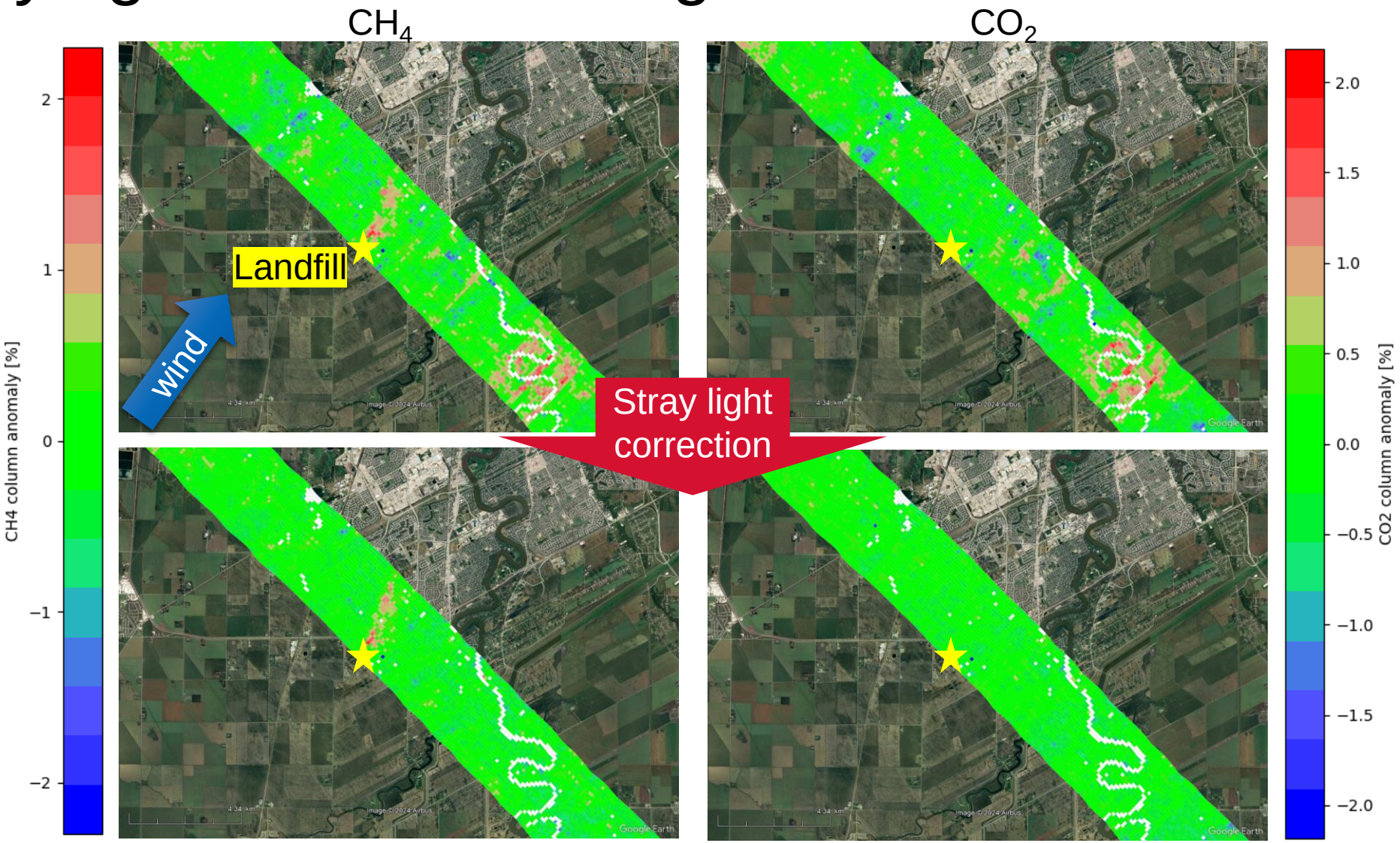
Estimated methane flux: 12.9 kt/yr



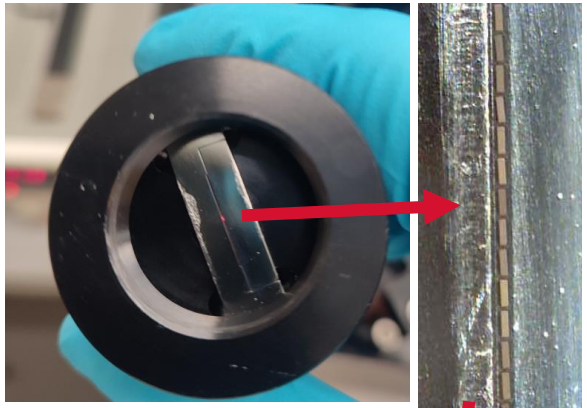
Minor impact of the stray light correction on proxy-corrected CH_4 column anomalies and flux estimates.

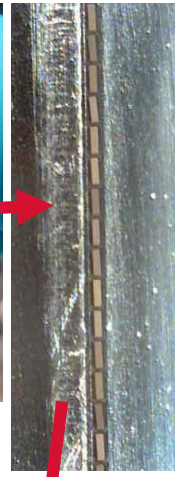
(Flux estimates were done with a mass balance approach)

Stray light correction single columns

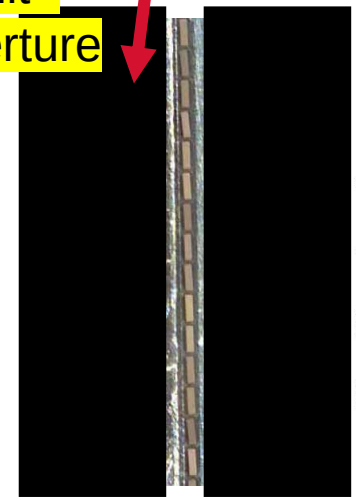


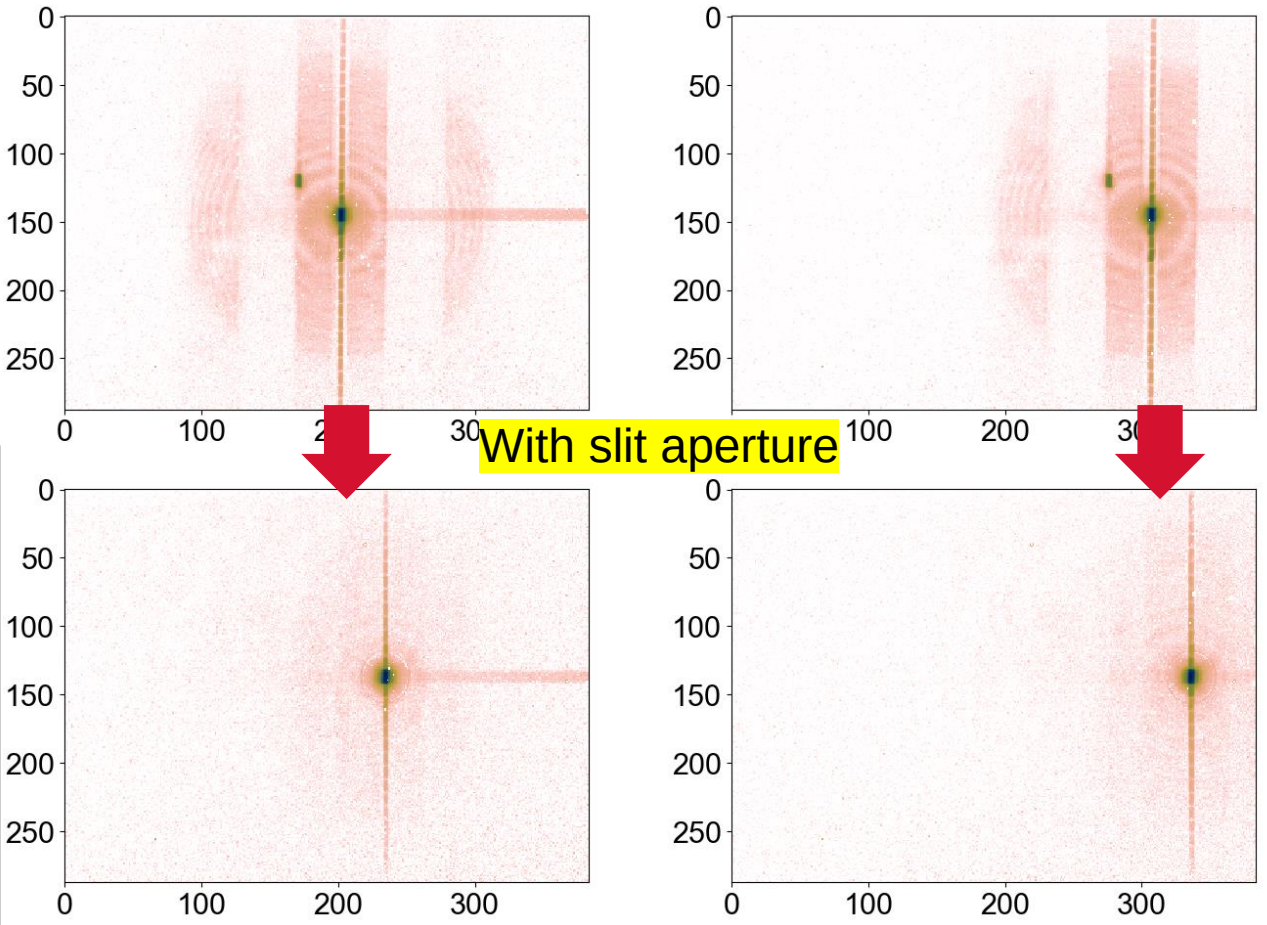
Stray light correction hardware solution





Slit - aperture





Estimated stray light before hardware improvement: $(\mathbf{3.9 \pm 0.5})\%$

Estimated stray light after hardware improvement: $(\mathbf{1.0 \pm 0.5})\%$

Summary and Conclusion

- Stray light is causing false anomalies in the retrieved single CH_4 and CO_2 columns
- Proxy method reduces stray light related artefacts if both absorption bands are contaminated by the “same” stray light in the same instrumental band
- Post-flight stray light correction improves the single-column data significantly
- Hardware improvement (4% → 1%) applied before the last campaign with MAMAP2D-Light in Queensland Australia, in summer 2023