The New Imaging Spectrometer MAMAP2D-Light – First Measurement Results

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Objective and basic measurement strategy of MAMAP2D-Light

Scientific goals of MAMAP2D-Light:

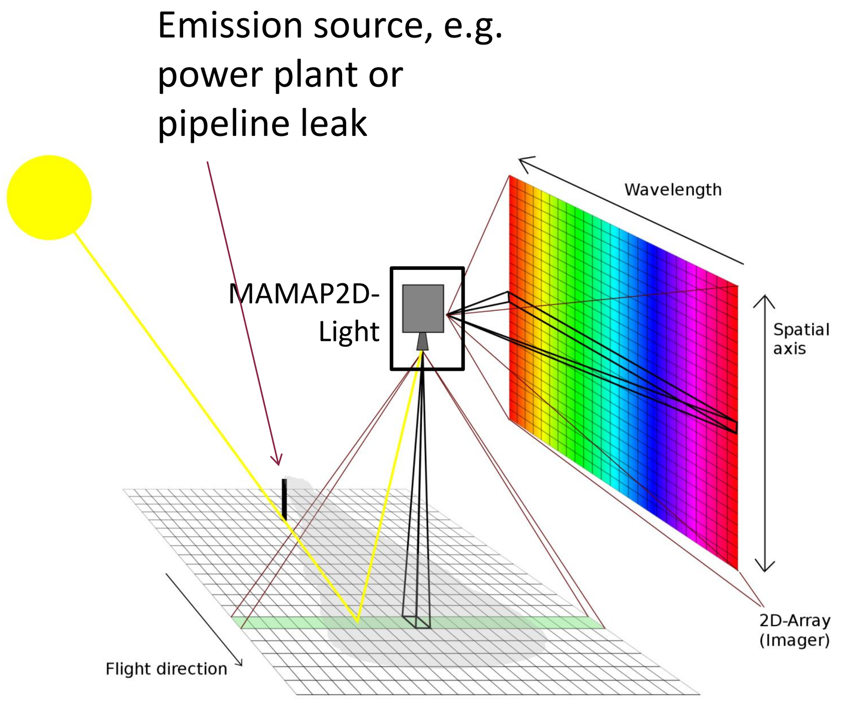
- Enhanced detection and quantification of anthropogenic CH_4 and CO_2 point sources with passive airborne imaging remote sensing
- Reduce uncertainty of point source emissions due to measurement noise

Technical goals of MAMAP2D-Light:

- 1-channel breadboard for 2-channel instrument MAMAP2D: Test of components and software
- Establish easy-to-deploy reliable instrument with monitoring capabilities

Passive airborne push broom imaging spectrometer:

- Records solar radiation reflected from ground
- Simultaneously observes multiple ground scenes across flight direction
- Spectrum of each ground scene is projected onto separate column(s) of the detector
- Due to movement of instrument 2D-Image of ground is recorded



MAMAP2D-Light instrument and deployment description

- Radiation upwelling from the ground scenes passes through a glass fiber bundle, which yields homogenized illumination of the detector within each ground scene.
- Each fiber core spectrum is projected on 6 detector rows
- Optical elements mounted on 6-axis adjusters custom-designed for MAMAP2D

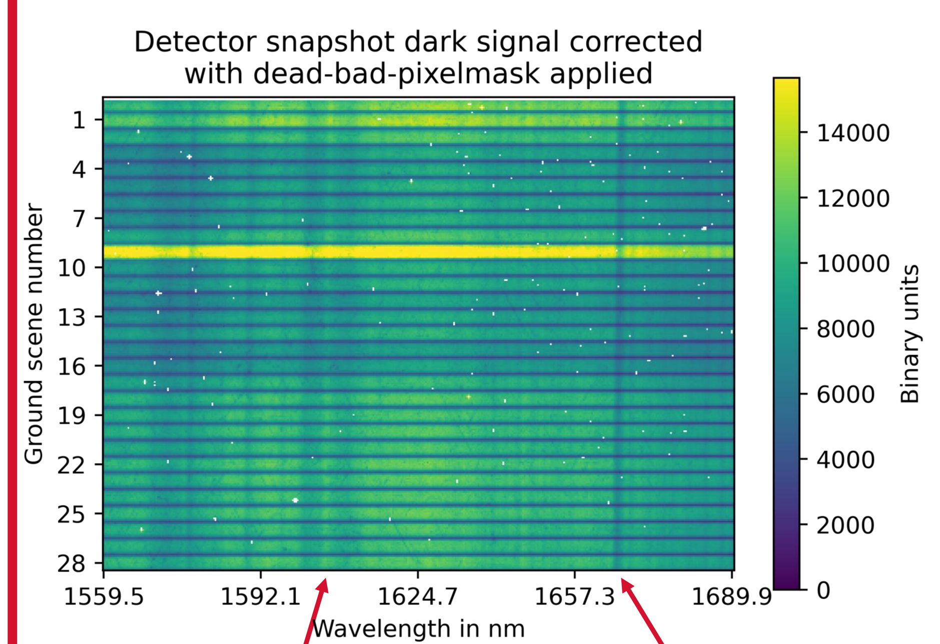
Spectral range	1559.5 nm – 1689.9 nm
# of spectral points	384 pixels
Spectral resolution (FWHM)	1.1 nm – 1.2 nm
SNR at half detector filling	~ 800
Spatial samples	28 ground scenes
Typical across track spatial resolution*	15 – 30 m
Typical along track spatial resolution*	5 – 10 m
Total weight	43.8 kg

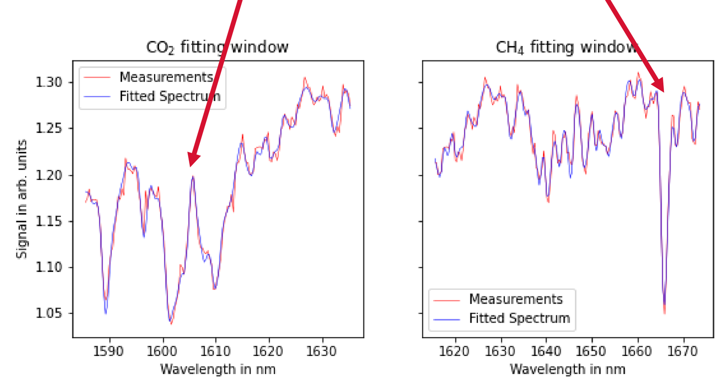
* At 1000m – 2000m flight altitude above ground

Integration of MAMAP2D-Light in the underwing pod of the Dimona HK 36 TTC ECO of Jade Hochschule Wilhelmshaven, a touring motor glider with low fuel consumption and low noise emissions.

Sensors in the underwing pods may have a gross weight of up to 45 kg on each side of the aircraft. Electrical power is provided by a 28 VDC/50 A bus system.

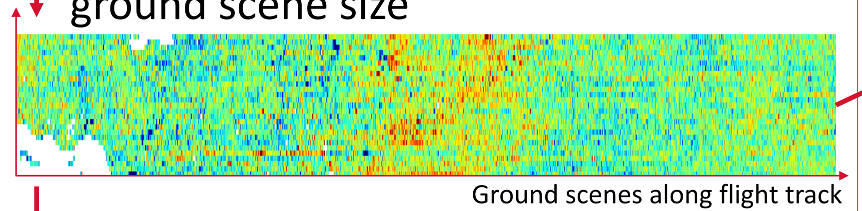
From detector readouts to fluxes – example case power plant Jänschwalde



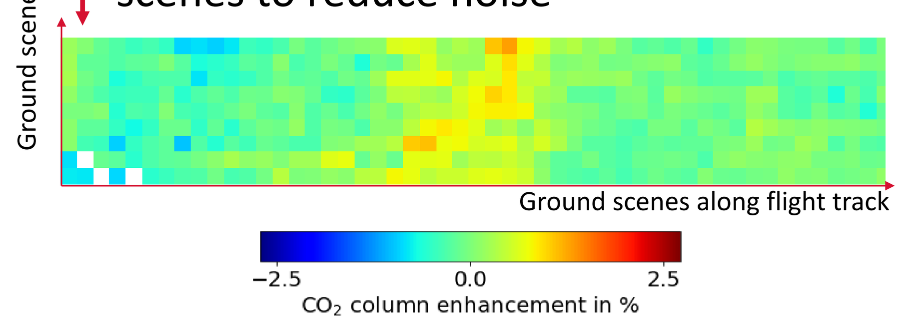


Retrieval of CH_4 and CO_2 enhancements out of the acquired spectra in two fit windows using the WFM-DOAS retrieval (Krings et al., 2011) results in column scaling factors for CH_4 and CO_2

CO_2 column enhancements for one flight track at 4 m x 33 m ground scene size



Binned to 100 m x 100 m ground scenes to reduce noise



Calculate flux with cross sectional flux method

$$\rightarrow F_{ct} = f \cdot \sum_i xCO_{2,enh,norm,i} \cdot CO_{2,back} \cdot k \cdot u \sin\alpha \cdot dx_i$$

$xCO_{2,enh,norm,i}$: Percentage increase in the plume relative to outside of the plume

$CO_{2,back}$: atmospheric column of CO_2 outside of the plume

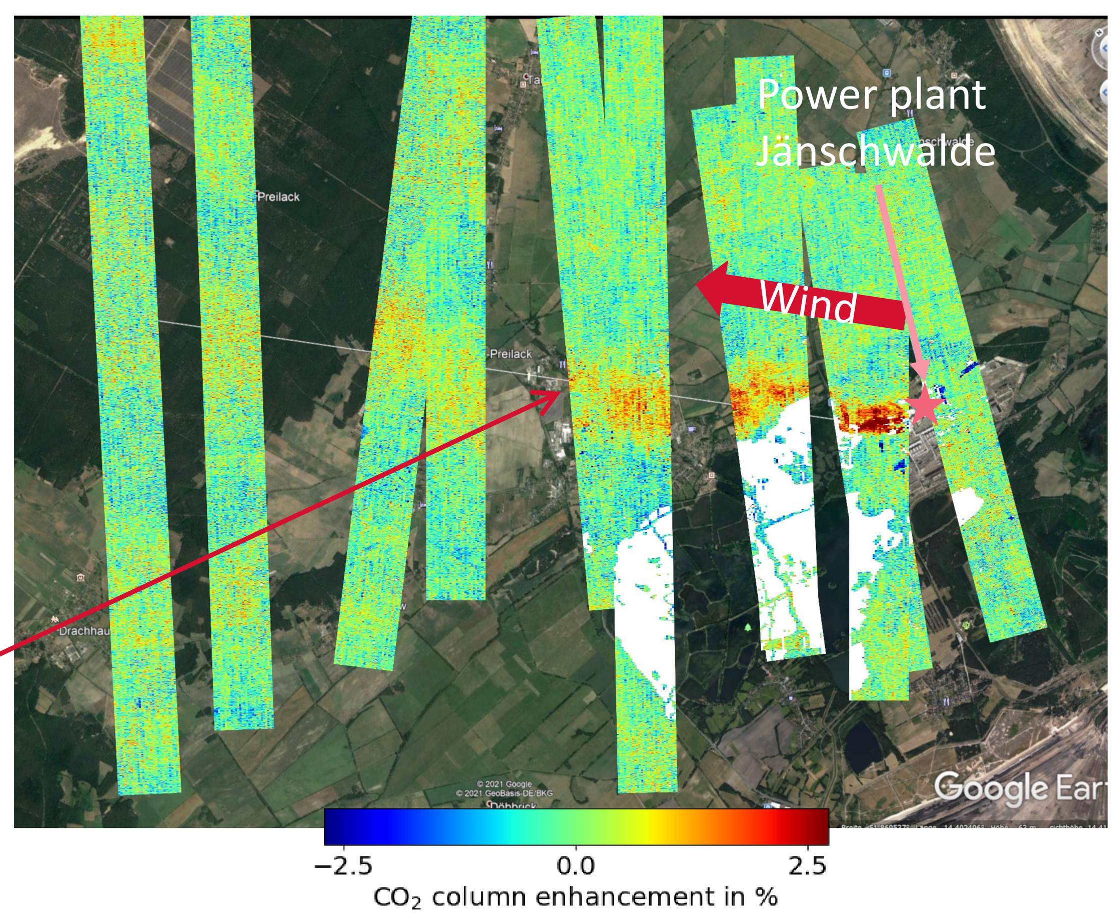
k: averaging kernel

u: mean wind speed over boundary layer, calculated from ERA5

α: Angle between flight track and wind vector

dx_i: Length of ground scene segment i

f: conversion factor to get result in Mt CO_2/yr



Measurement flight over coal fired power plant Jänschwalde. The non binned flight track sections orthogonal to the plume are overlayed over Google Earth imagery. The emission plume is visible up to 10 km away from the power plant; Background Image: Google Earth, earth.google.com/web/

Flux estimation for power plant Jänschwalde:

- Inversion of measurements made during the flight on 17.06.2021 yield an emission of **(10.8 ± 1.9) Mt CO_2/yr** (only valid for time of overflight)
- Uncertainty estimation based on gaussian error propagation of the cross-sectional flux formula
- Largest contribution to uncertainty from wind speed uncertainty (± 1.6 Mt CO_2/yr)
- Contribution due to measurement noise is negligible (± 0.006Mt CO_2/yr)
- Power plant Jänschwalde emitted **~11.7 Mt CO_2 in KW 24, 2021** based on average emissions for 2020 and percentage full load in KW24 and in 2020[a, b]

Performance estimation of MAMAP2D-Light:

- **Precision** (standard deviation) of binned retrieval results in background regions is **0.23 %**
- In the **non-binned** ground scenes, the **precision** (standard deviation) is **still 0.7 %**

Summary and Conclusion

- MAMAP2D-Light performed well during the first measurement flight
- Binning increased ground scene precision to ~0.23%
- Emissions of power plant Jänschwalde fit estimated emissions well within the 1-sigma uncertainty range.

Selected references

[a] LfU Brandenburg, „Abschätzung der Treibhausgasemissionen im Land Brandenburg in 2020“, 2021, https://lfu.brandenburg.de/sixcms/media.php/9/Klimagase-Corona2020.pdf, last access: 12.11.2021

[b] Percentage full load of power plants, https://energy-charts.info/charts/percentage_full_load/chart.htm, last access 15.11.2021

Krings, T., Gerilowski, K., Buchwitz, M., Reuter, M., Tretner, A., Erzinger, J., Heinze, D., Pflˈuger, U., Burrows, J. P., and Bovensmann, H. MAMAP – a new spectrometer system for column-averaged methane and carbon dioxide observations from aircraft: retrieval algorithm and first inversions for point source emission rates. Atmos. Meas. Tech., doi:10.5194/amt-4-1735-2011, 2011

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