EM27/SUN activities at Heidelberg – mobile deployments on ships and vans

Institute of Environmental Physics, Heidelberg University

André Butz, Ralph Kleinschek, Marvin Knapp,
Benedikt Hemmer, Valentin Hanft, Ken von Bünau ...

+ many student contributors

+ close collaboration with KIT, NIES, TUM and other institutes for field campaigns

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Klappenbach, https://doi.org/10.5194/amt-8-5023-2015, AMT, 2015;
Butz et al., https://doi.org/10.5194/amt-10-1-2017, AMT, 2017;
Luther et al., https://doi.org/10.5194/amt-12-5217-2019, AMT, 2019;
Knapp et al., https://doi.org/10.5194/essd-2020-132, ESSD, 2021;

Ship-going EM27/SUN

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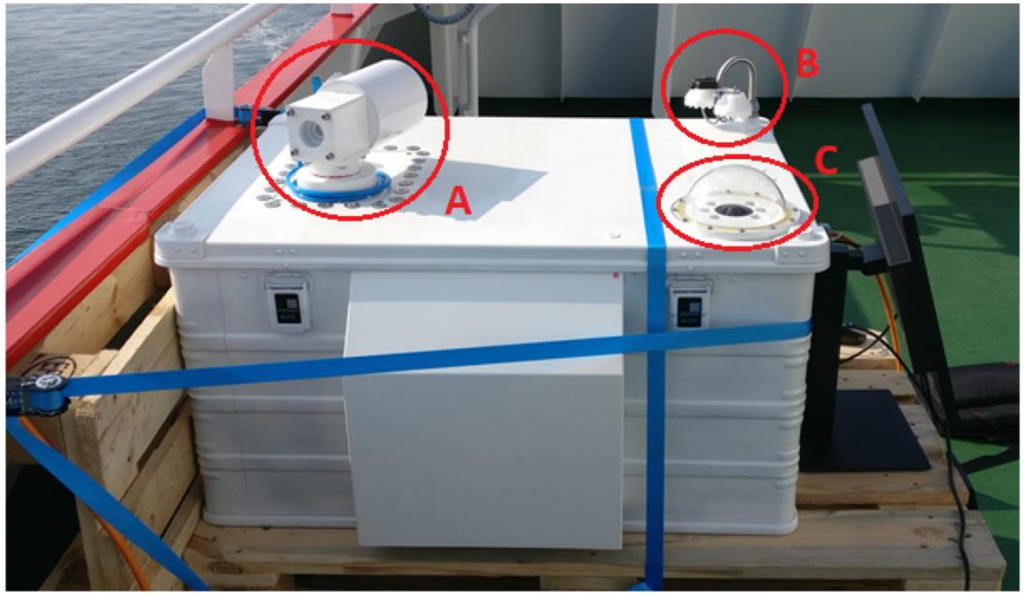
Mar. 2014: **RV Polarstern** - Atlantic

June 2019: **RV Sonne** - Pacific

Mar. 2021: **RV Mirai** – Japanese coast, testing for operational deployment in collaboration with NIES (National Institute for Environmental Studies).



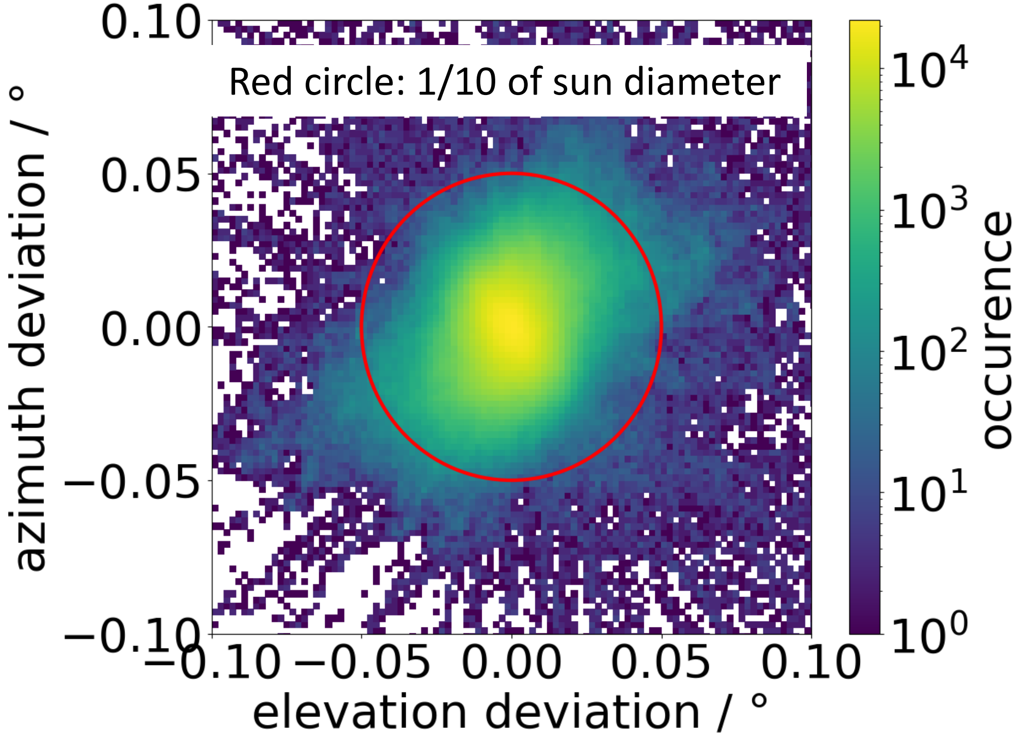
Ship-going variant of EM27/Sun Fourier Transform Spektrometer (Bruker Optics) with custom-built sun-tracker und sealed housing.

[Klappenbach, https://doi.org/10.5194/amt-8-5023-2015, AMT, 2015; Knapp et al., https://doi.org/10.5194/essd-2020-132, ESSD, 2021]

Ship-going EM27/SUN

Custom-built sun-tracker enables accurate pointing to the center of the solar disk under typical platform motion.

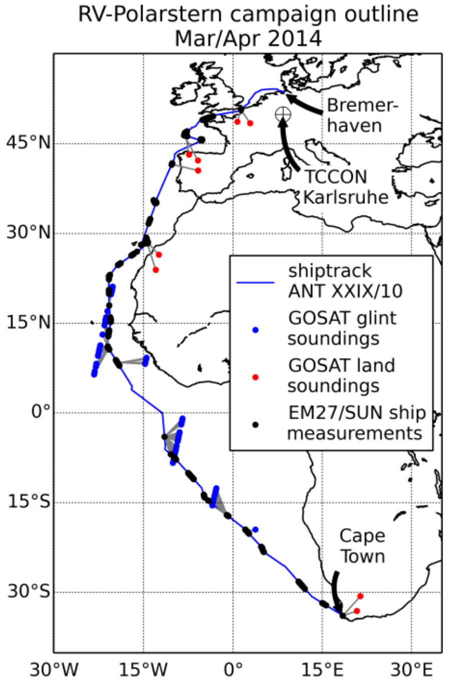
Residual pointing error during ship cruise (diameter solar disk 0.53°).

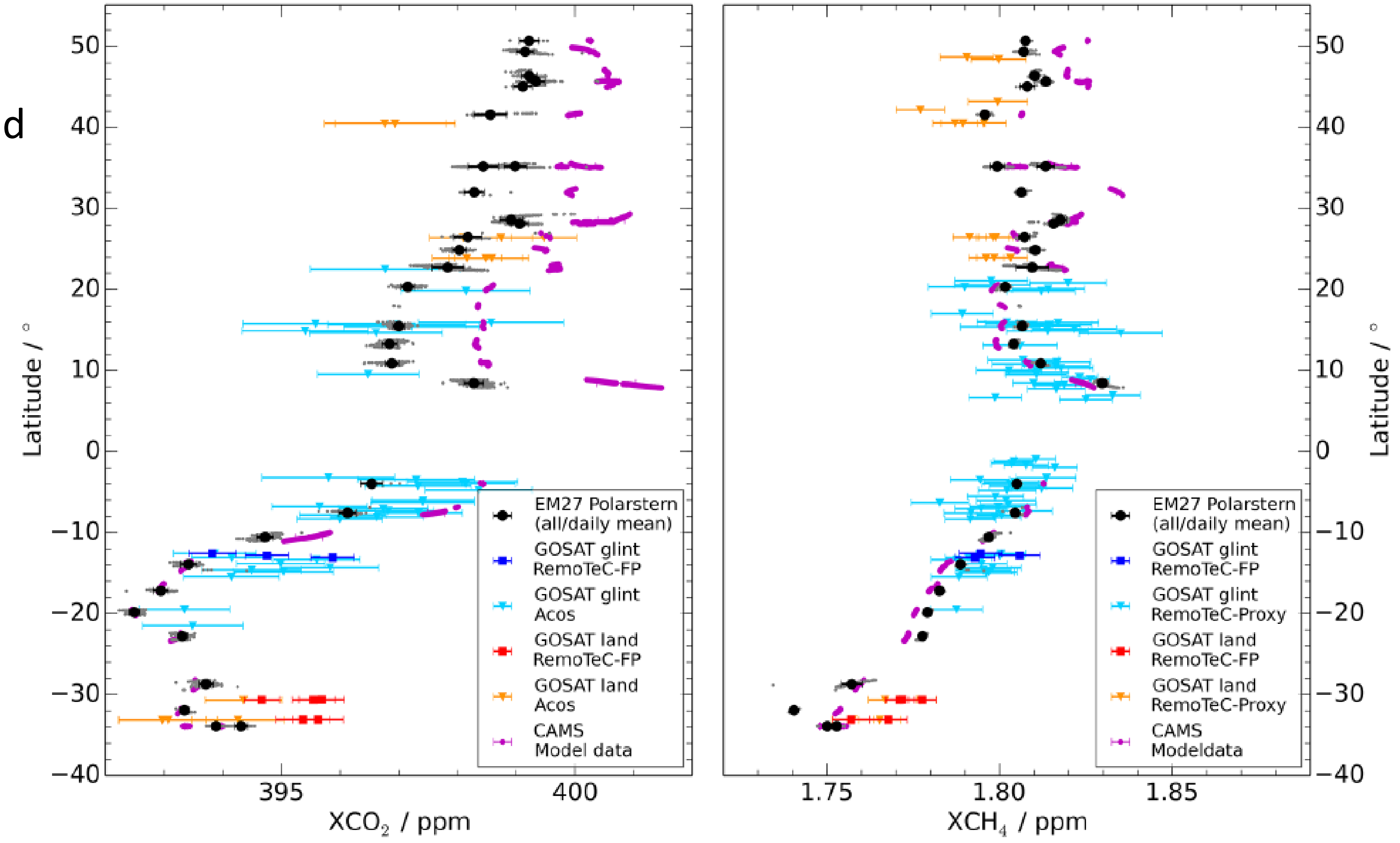


[Klappenbach, https://doi.org/10.5194/amt-8-5023-2015, AMT, 2015;
Knapp et al., https://doi.org/10.5194/essd-2020-132, ESSD, 2021]

Ship-going EM27/SUN

RV Polarstern 2014: South-North transect through the Atlantic Ocean for satellite and model validation of XCO_2 and XCH_4.





[Klappenbach, https://doi.org/10.5194/amt-8-5023-2015, AMT, 2015]

Ship-going EM27/SUN

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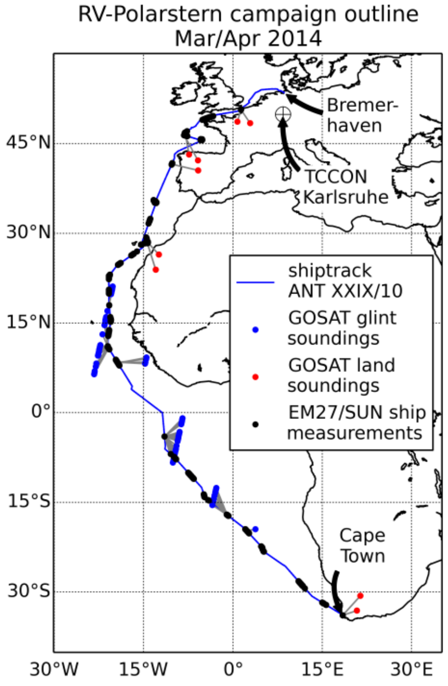
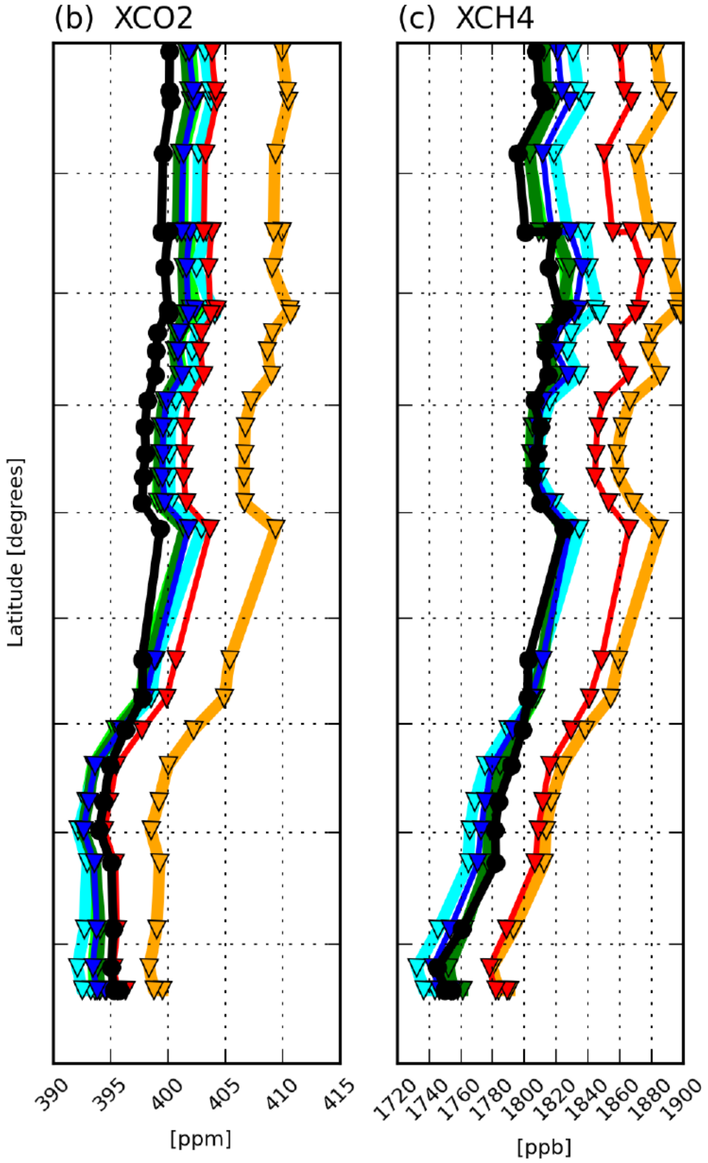




- ECMWF finds a **bias in their hemispheric greenhouse gas gradients**.
- **Tuning of the „mass-fixer“** in CAMS model to fit the measured gradients.

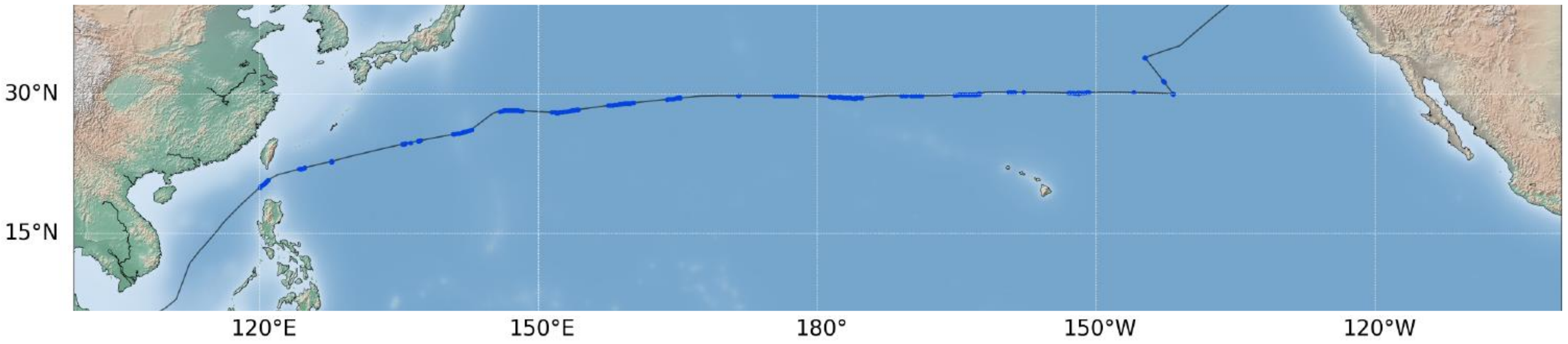
Black: ship-borne measurements

Color: various model settings

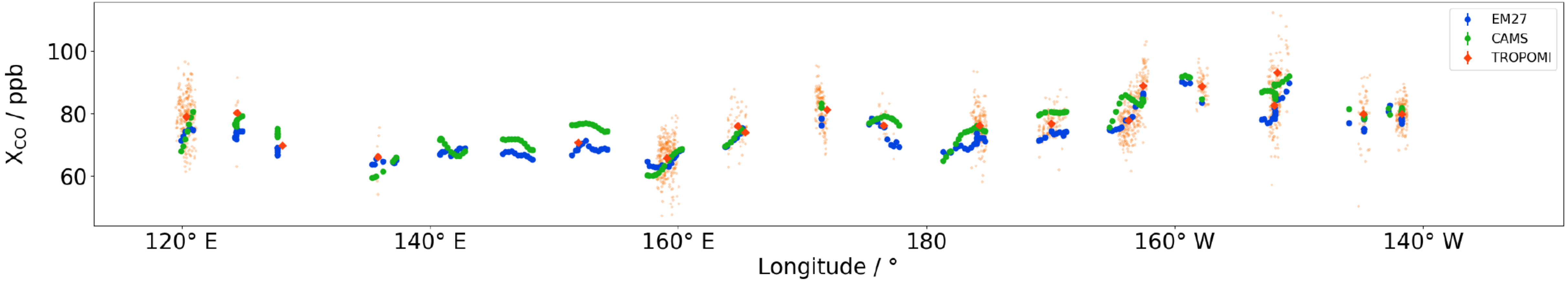
[Agusti-Panareda, https://doi.org/10.5194/gmd-10-1-2017, GMD, 2017]

Ship-going EM27/SUN

RV Sonne 2019: East-West transect through the Pacific Ocean for satellite and model validation of XCO_2, XCH_4, and XCO.

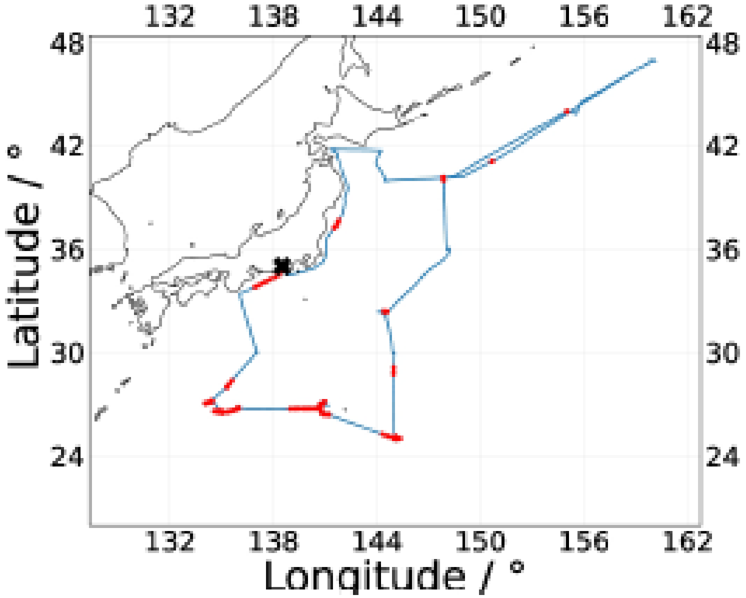


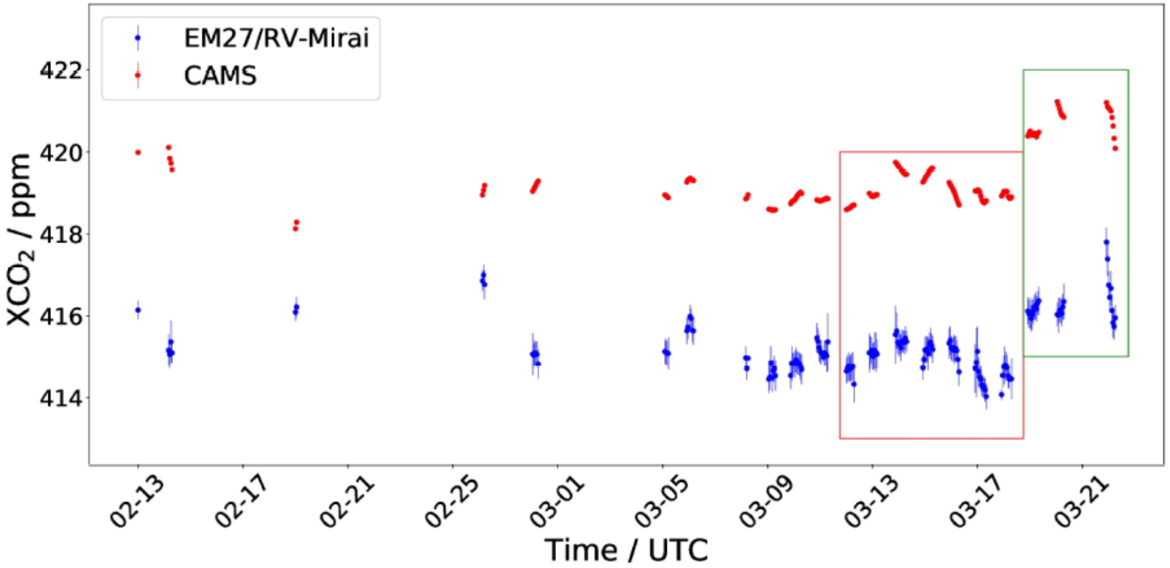
Ship-borne measurements and S5P/TROPOMI XCO agree to within a few ppb, likewise for CAMS.

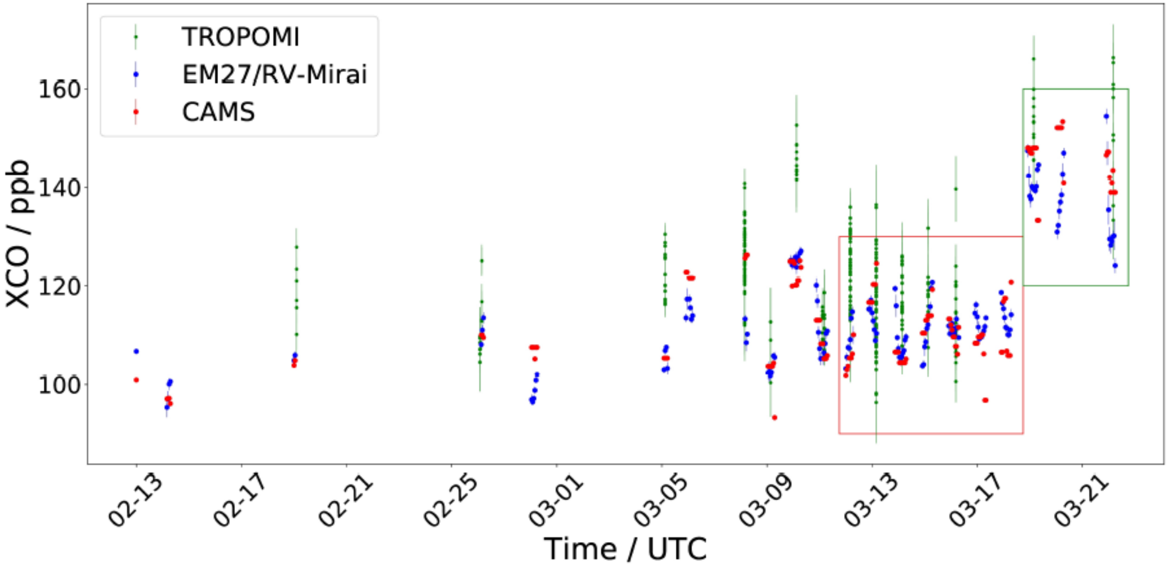


[Knapp et al., https://doi.org/10.5194/essd-2020-132, ESSD, 2021]

Ship-going EM27/SUN





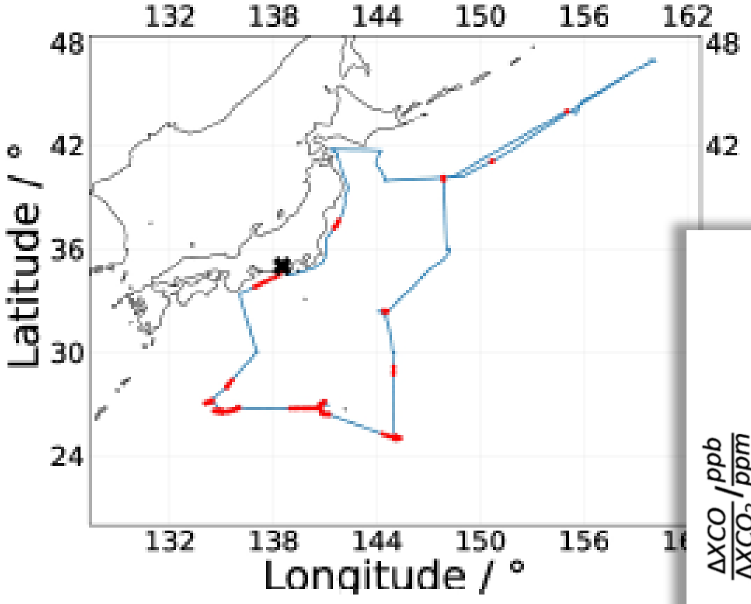


RV Mirai 2021: Pacific Ocean in the vicinity of Japan

Correlated enhancements in XCO_2 and XCO downwind of East-Asia

[Butz et al., under review, Frontiers, 2021]

Ship-going EM27/SUN



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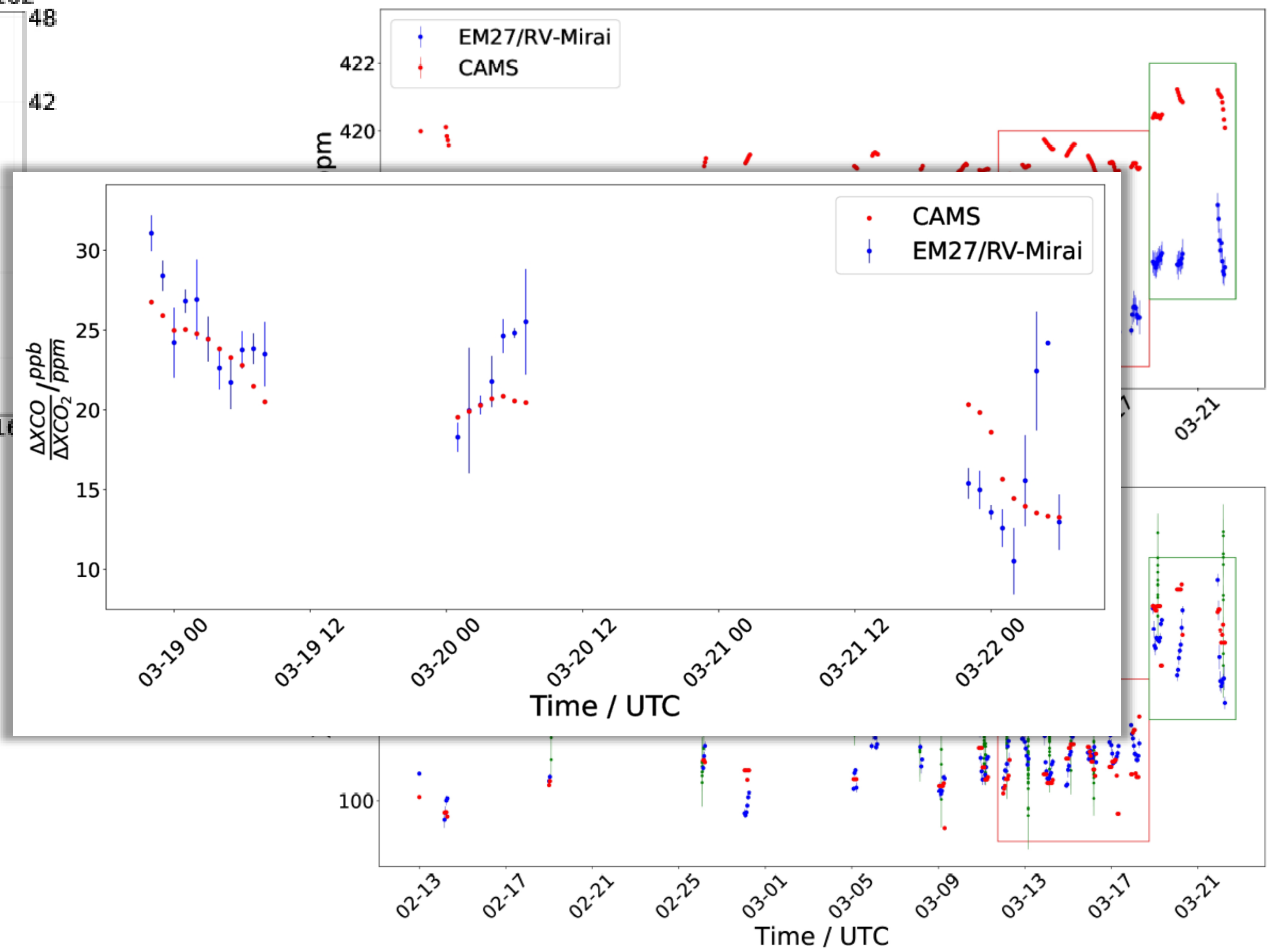
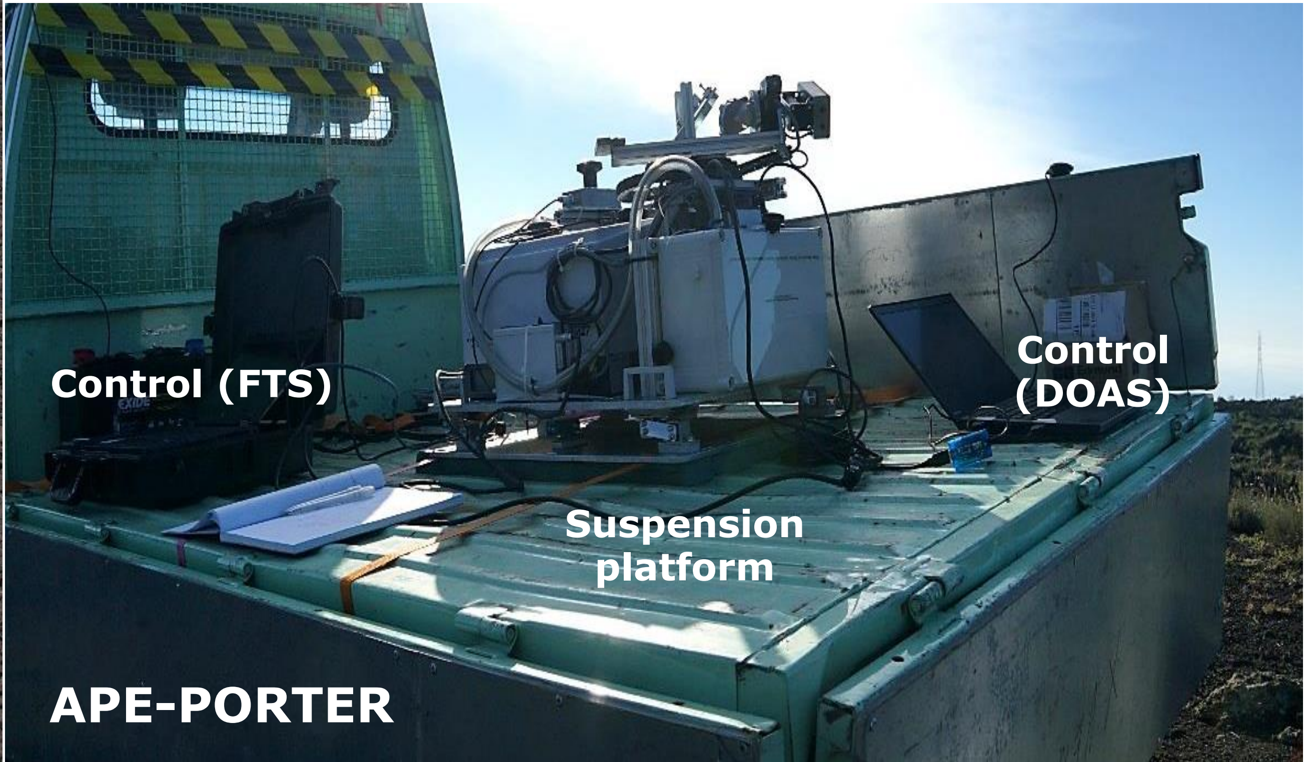


[Butz et al., under review, Frontiers, 2021]

Volcano monitoring

Volcanic CO_2/SO_2 emissions at Mt. Etna, Sicily (Sep. 2016)



Volcano monitoring

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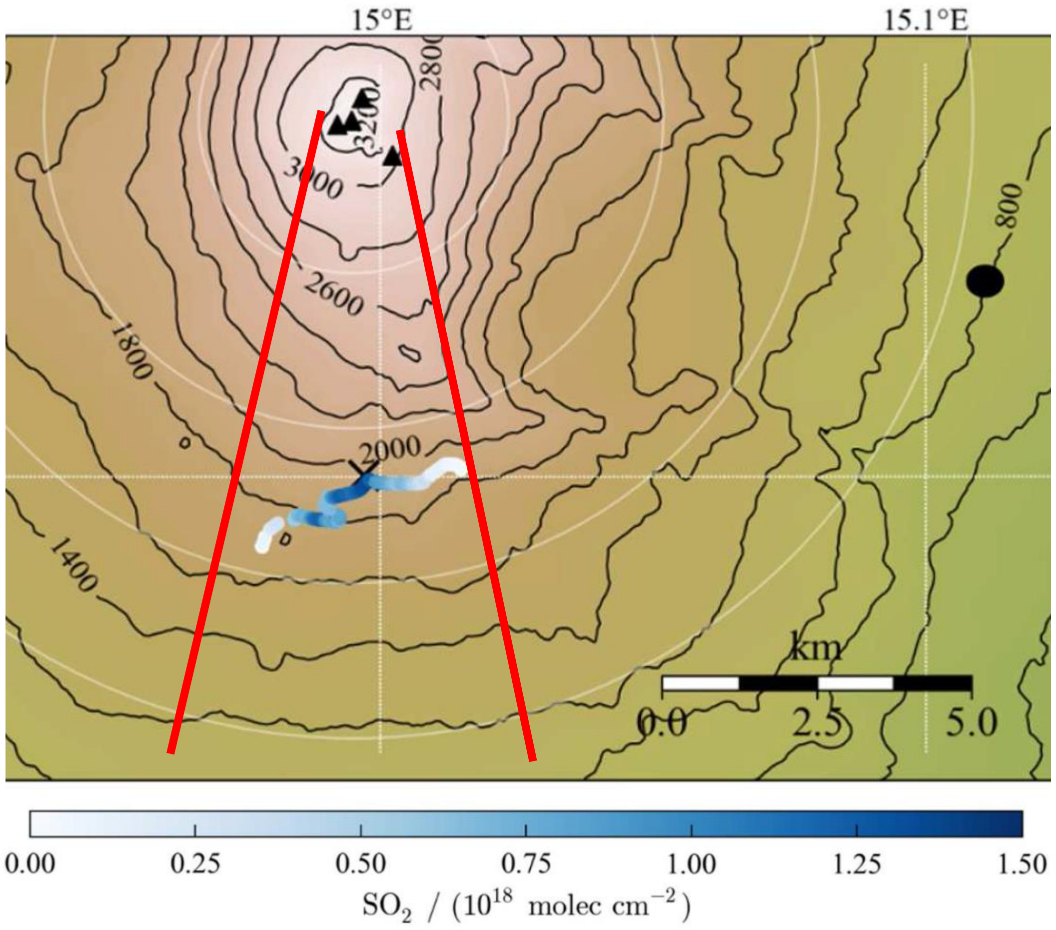

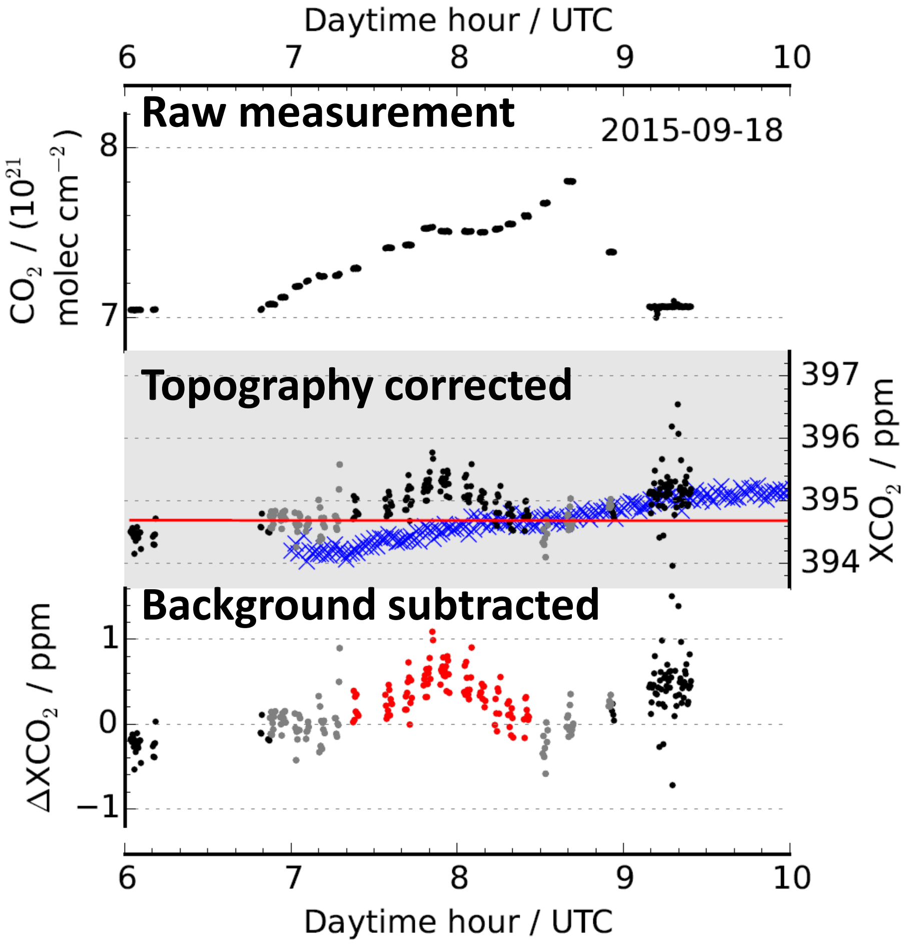

Detection of volcanic CO_2 plume (0.5 ppm above background) in safe distance (5-10 km) from source.

[Butz et al., https://doi.org/10.5194/amt-10-1-2017, AMT, 2017]

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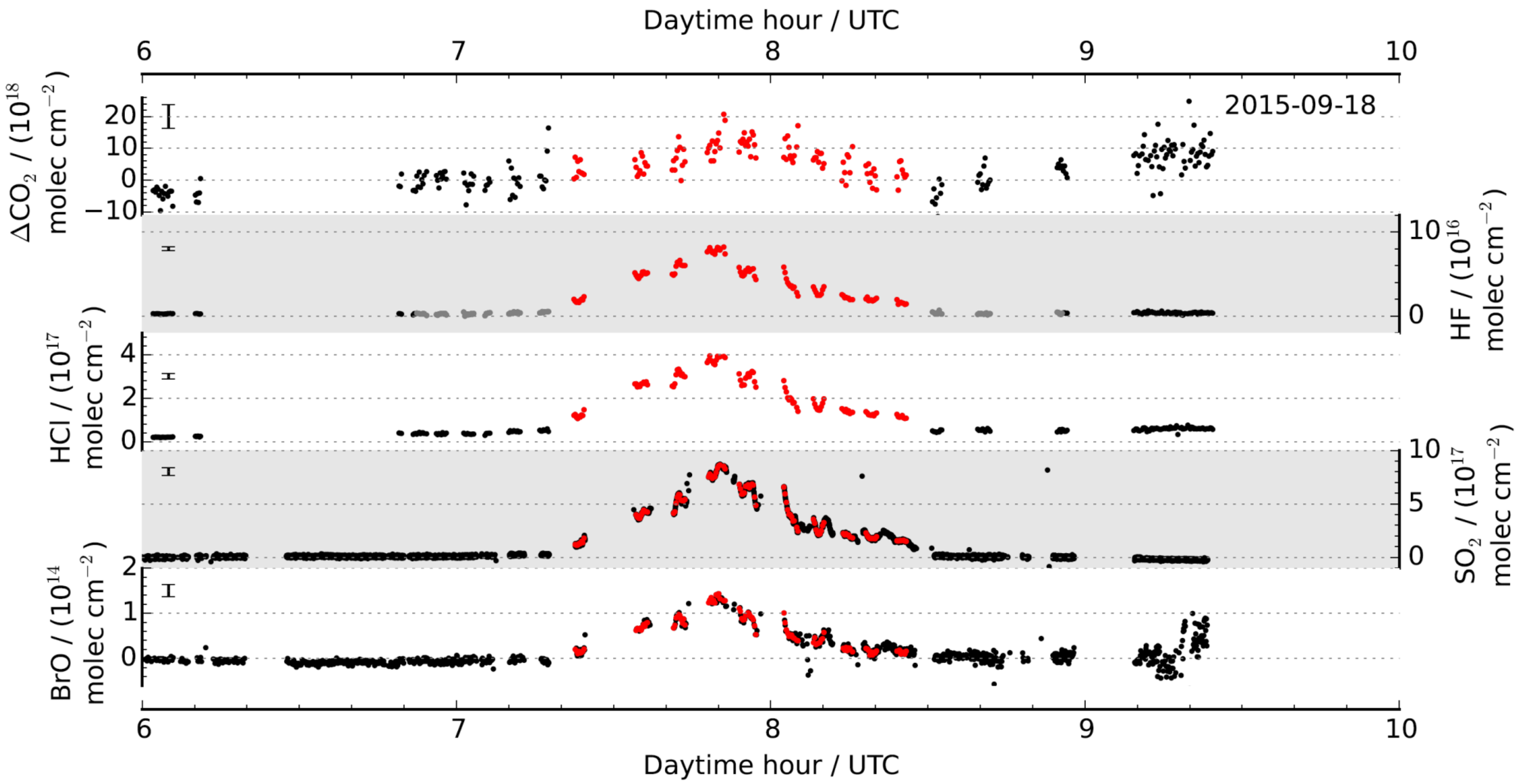


Co-sampling of volcanic CO_2 enhancements and SO_2, HF, HCl, BrO allows for **activity tracking and disentangling plume evolution from activity changes**.

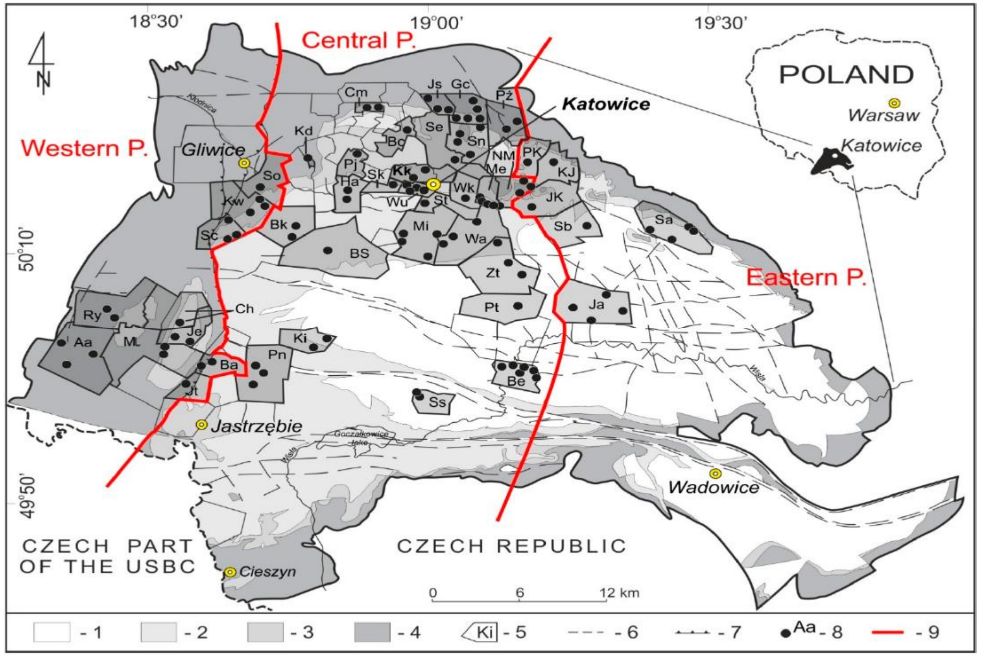
CO_2/SO_2 ratios, for example, have been suggested promising **indicators for changes in volcanic activity**.

[Butz et al., https://doi.org/10.5194/amt-10-1-2017, AMT, 2017;]

Coal mine CH_4 emissions

Luther et al., AMT, 2019

CH_4 coal mine emissions in the Upper Silesian Coal Basin, Poland (May/June 2018)

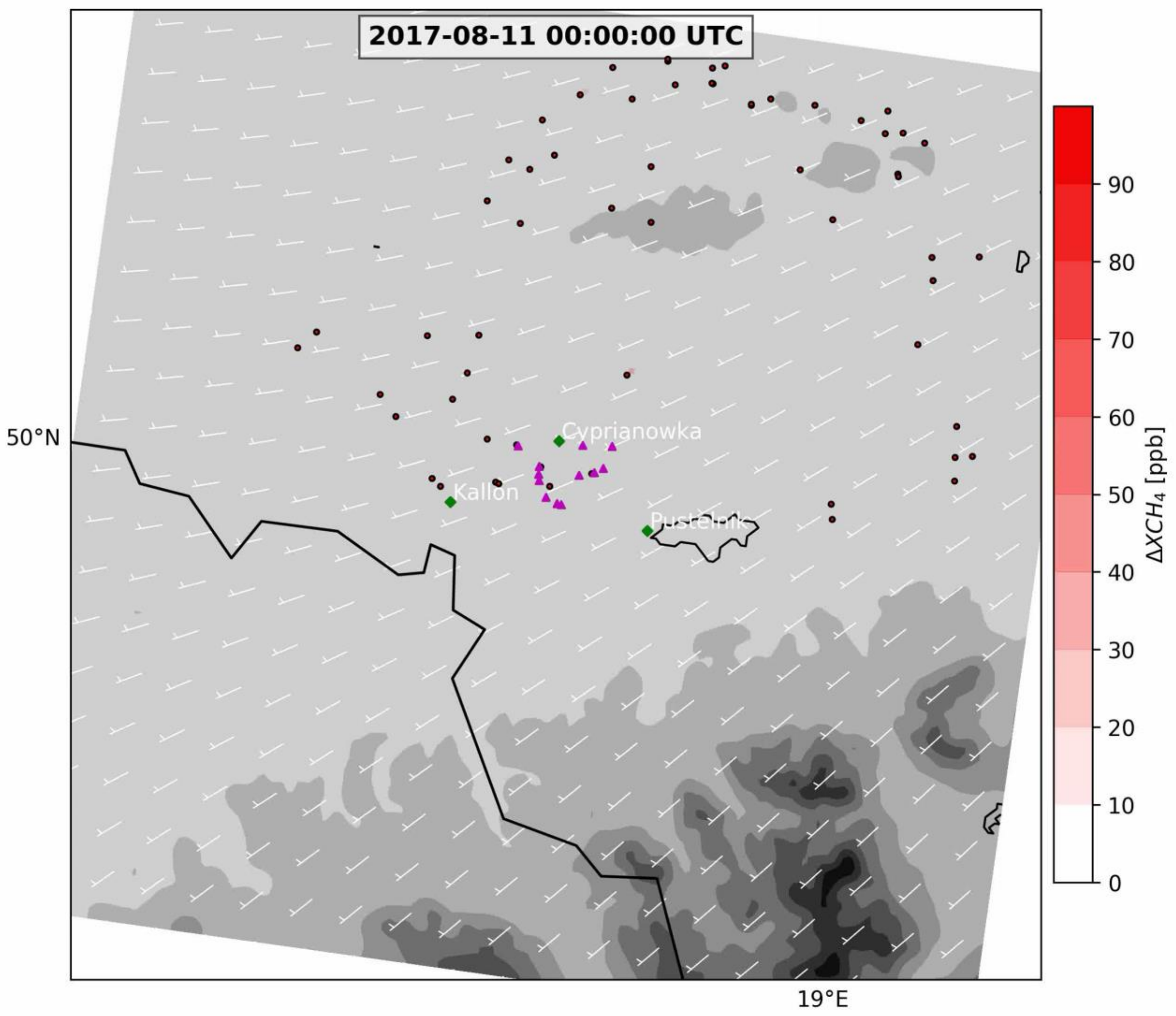


[Parzentny, https://doi.org/10.3390/min10050422, Minerals, 2020]

Coal mine CH_4 emissions

CH_4 coal mine emissions in the Upper Silesian Coal Basin, Poland (May/June 2018):

Some 50+ coal mine ventilation shafts release CH_4 into the atmosphere, estimated emissions of the basin: 400-600 kt/a with individual shafts emitting up to 20 kt/a.



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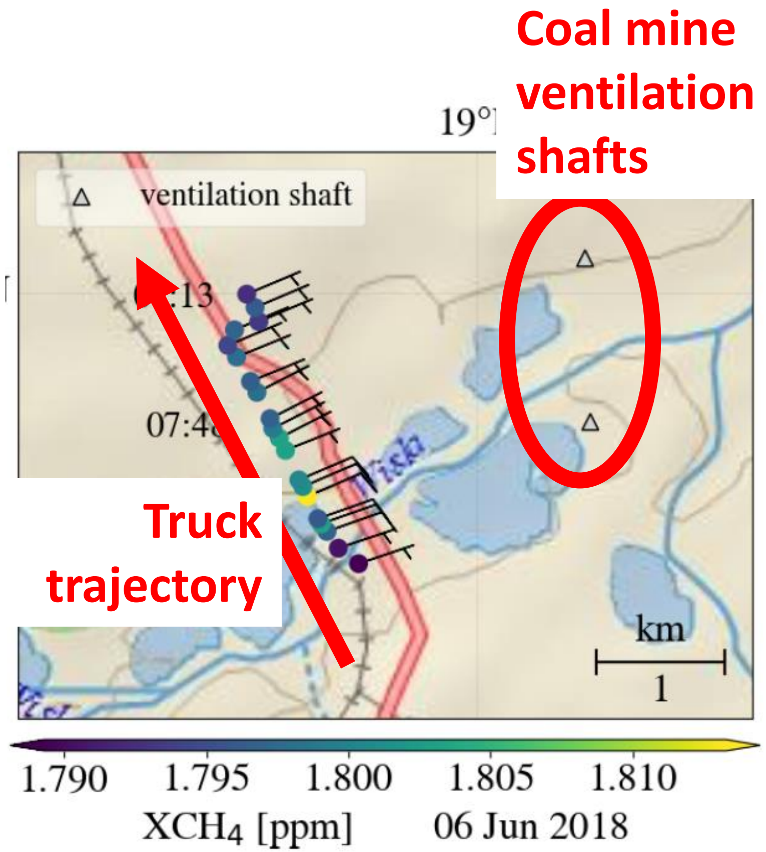
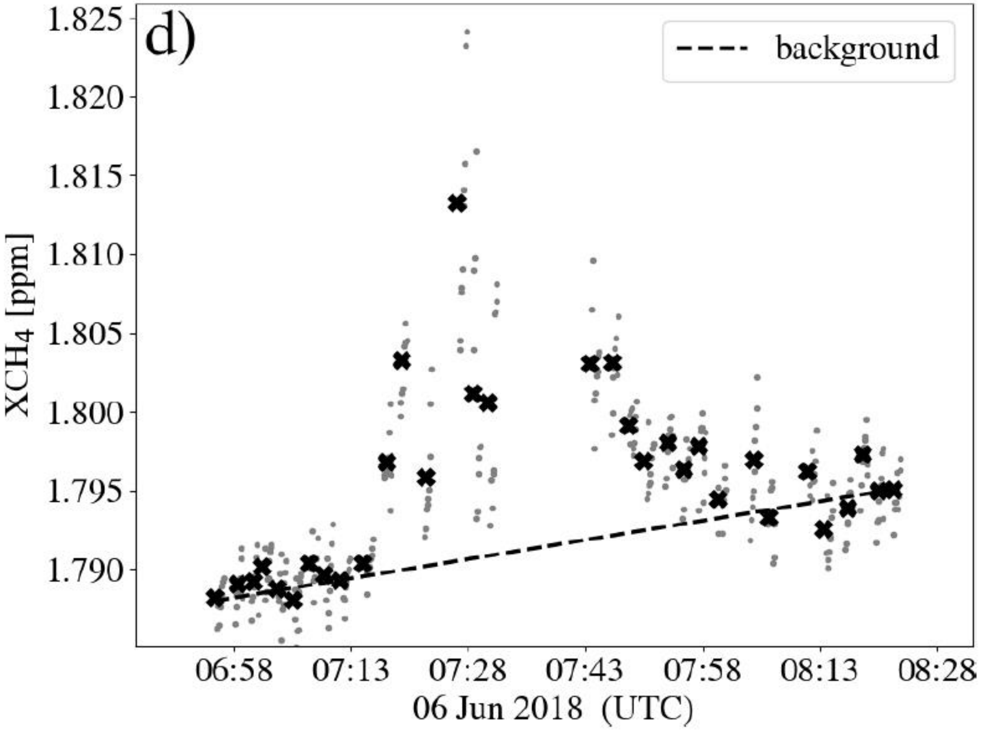
[Luther et al., https://doi.org/10.5194/amt-12-5217-2019, AMT, 2019]

Coal mine CH_4 emissions

CH_4 coal mine emissions in the Upper Silesian Coal Basin, Poland (May/June 2018):

- 1 mobile EM27/Sun
- 4 stationary EM27/Sun
- 3 Wind-Cube Doppler lidars for wind measurements.





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[Luther et al., https://doi.org/10.5194/amt-12-5217-2019, AMT, 2019]

Coal mine CH_4 emissions

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CH_4 coal mine emissions in the Upper Silesian Coal Basin, Poland (May/June 2018):

- 1 mobile EM27/Sun
- 4 stationary EM27/Sun
- 3 Wind-Cube Doppler lidars for wind measurements.

Instantaneous emission estimates with 15-40% errors.

$$Q = \sum_i \Delta XCH_4(x_i, y_i) U_{eff}(x_i, y_i)\, dy_i \frac{M(CH_4)}{10^9 \times N_a}$$

ΔXCH_4: CH_4 enhancement
U_{eff}: effective wind speed
dy: perpendicular path element

Date and time	estimated emissions [kt/a]	combined σ [kt/a]	combined σ %	E-PRTR 2014 [kt/a]
24 May 7 - 8 am	**6**	**1**	19	**9.63**
24 May noon	**10**	**1**	15	**9.63**
01 June 8 - 10 am	**110**	**38**	35	-
06 June 7 - 8 am	**17**	**3**	18	**24.3**
06 June noon	**81**	**13**	16	**$\sim$ 80**

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[Luther et al., https://doi.org/10.5194/amt-12-5217-2019, AMT, 2019]

Mobile EM27/SUN

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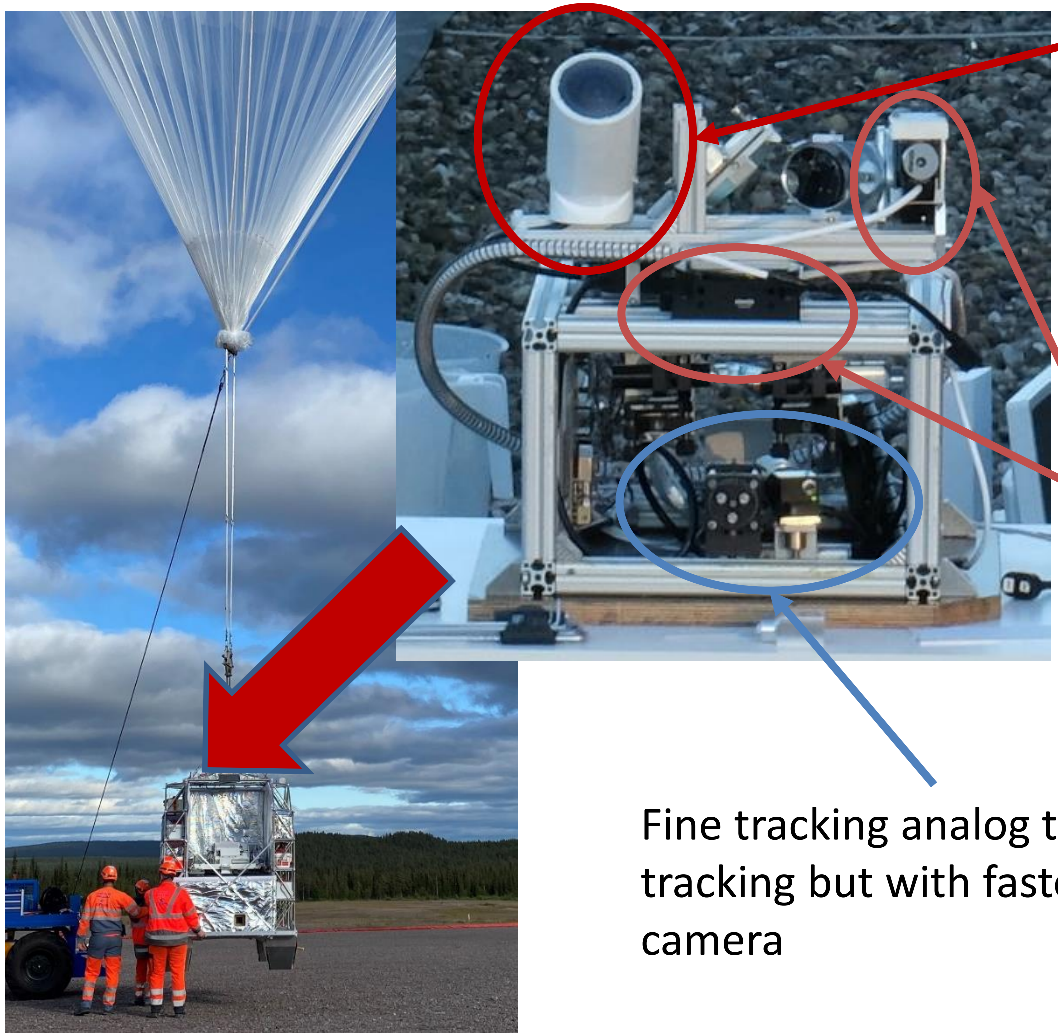
Enabling tech: custom-built, fast, self-orienting sun-tracker

Deployment on a stratospheric balloon (DOAS)

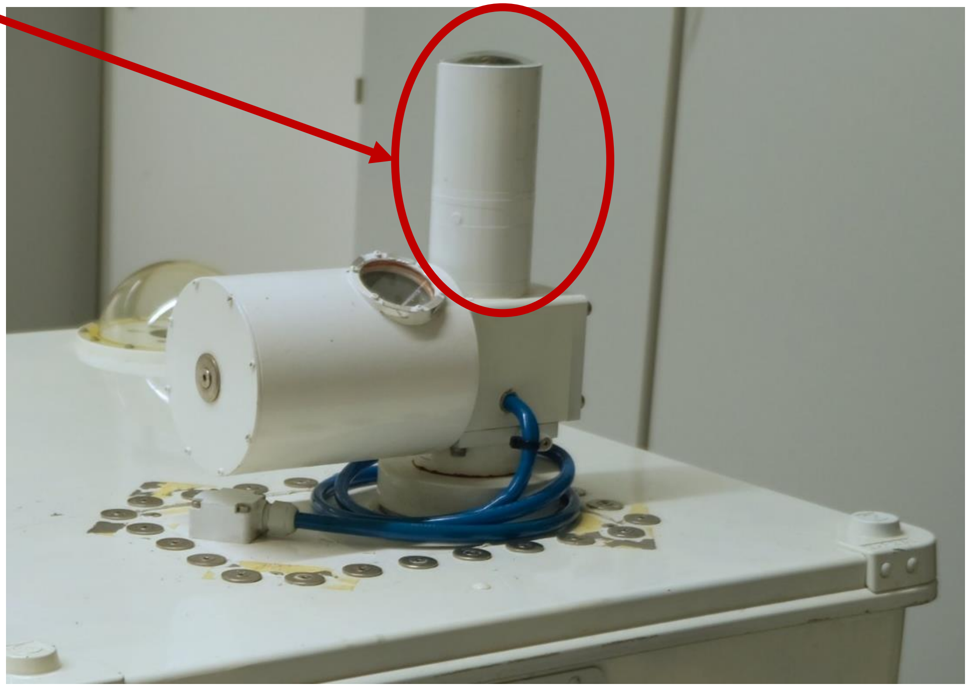
Deployment on ships (Bruker EM27 on RV Mirai)



Coarse tracking camera setup

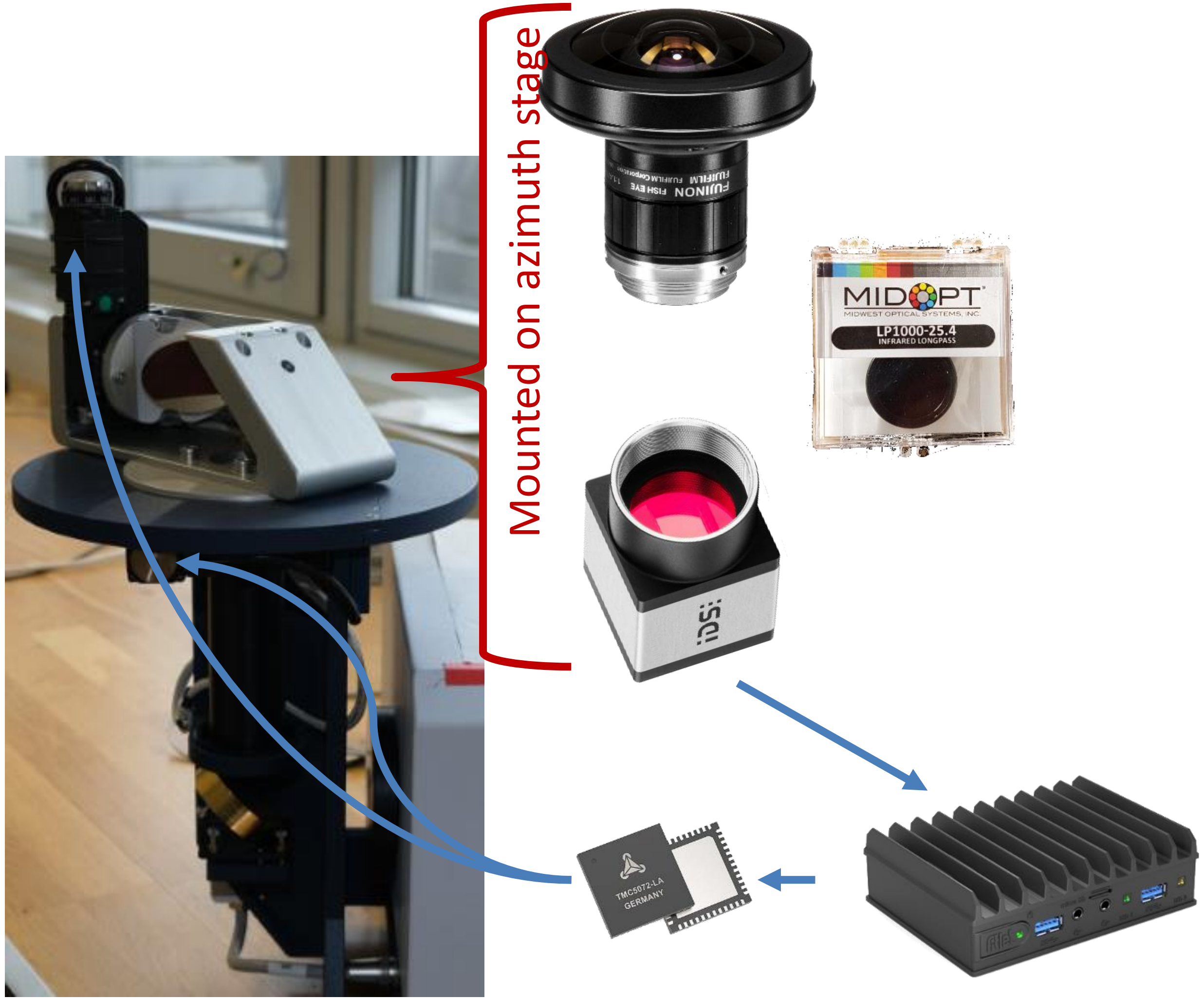
Same rotation stages as used in the original Bruker tracker

Fine tracking analog to EM27 tracking but with faster camera



Enabling tech: custom-built, fast, self-orienting sun-tracker

Coarse-tracking hardware



FUJINON f-theta lens (FOV 185°)	€ 500,-
Long pass (@ 1000 nm)	€ 100,-
IDS UI3280 Camera	€ 700,-
TMC 5072 stepper driver	€ 60,-
Embedded computer	€ 600,-
	~ 2 k€

For the coarse tracking, a camera with an f-theta lens is mounted directly on the azimuth stage.

A custom-made software on an embedded computer processes the images from the camera and determines the rough relative location of the sun.

A TMC motor driver operates the original Bruker rotation stage.

Enabling tech: custom-built, fast, self-orienting sun-tracker

Fine-tracking hardware

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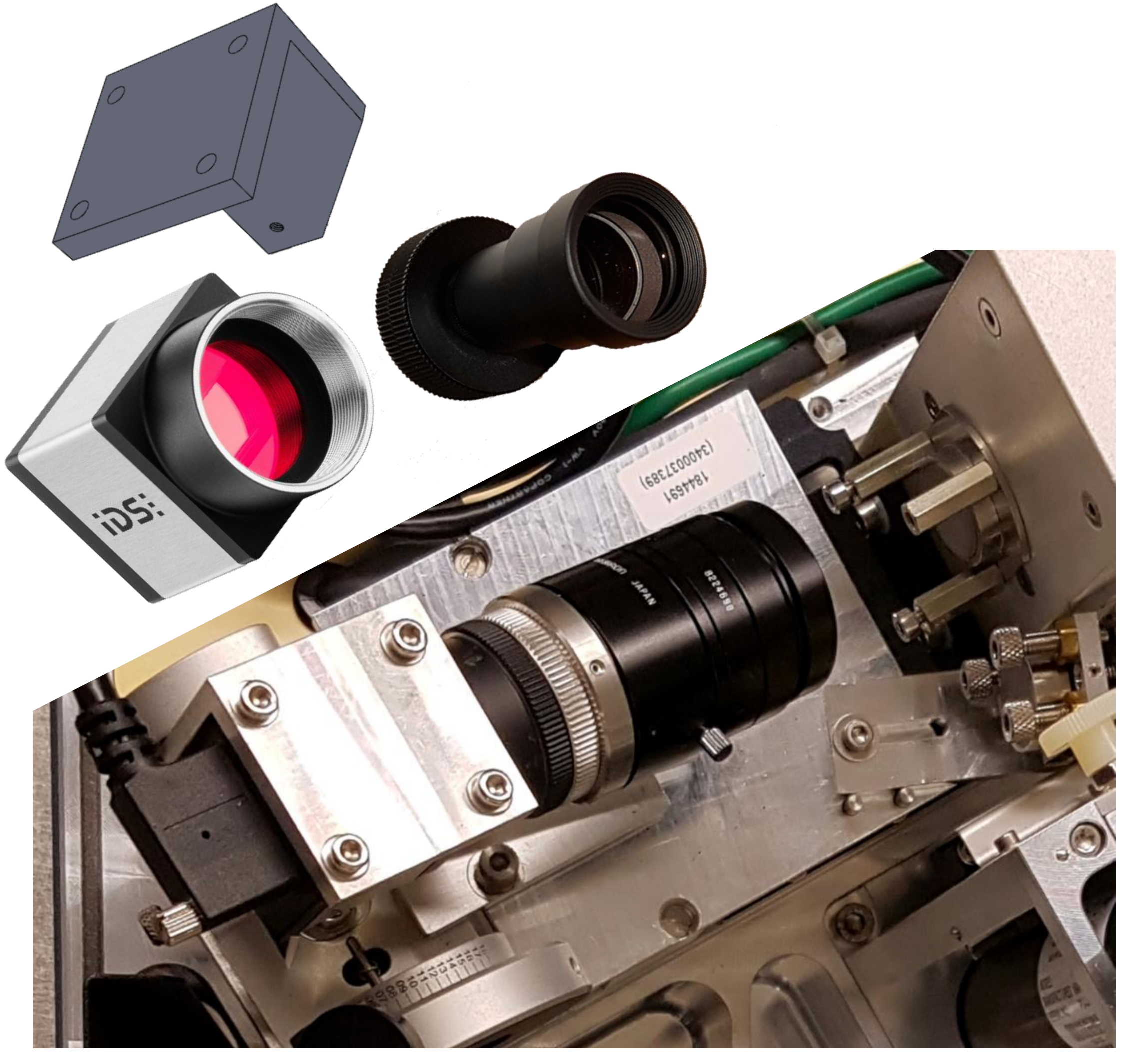
Camera adapter plate	€ 80,-
Lens with macro extension	€ 100,-
IDS UI3140 Camera	€ 700,-
	~ 1 k€

Fast fine tracking requires the change of the internal camera.

We use an IDS camera to reach frame rates up to 125 fps (without a defined area of interest or binning).

The other form factor of the camera requires an adapter plate. We will use a smaller lens for the next upgrade for better mechanical stability.

The fine-tracking software is custom-built and needs tuning (PID) for the considered application.



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