Using the EM27/SUN FTS for open path measurements of GHGs

COCCON community telco Oct-25-2022

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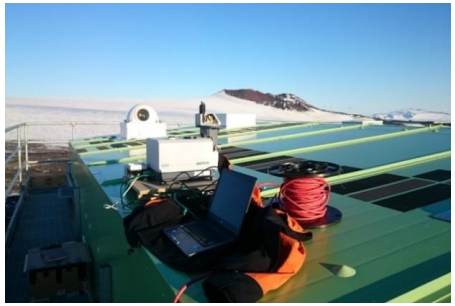
The EM27/SUN: a wide range of applications

Travel standard for TCCON



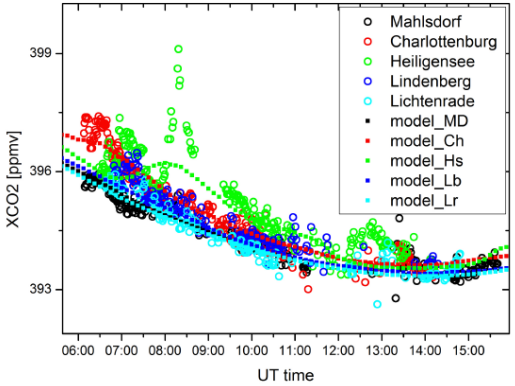
Arrival Heights
(NIWA, Pollard)

FRM4GHG / ESA travel standard unit
(NIES, UoT, …, TUM, KIT)

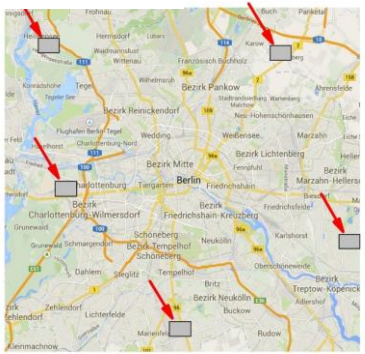
Supplement TCCON sites (satellite validation)

e.g. Mexico, Namibia, India, …

Quantify localized sources



Berlin



OP measurements using the EM27/SUN FTS

There is a well-developed state-of-art & dedicated setups, why re-investigate?

Numerous EM27/SUN spectrometers are around, aim at co-use in their current solar absorption configuration for OP measurements as well:

- Use available spectrometer during night time and overcast condts
- Alternating solar absorption + OP: “In-situ“ measurements of PBL concentrations in the same unit system as column-integrated measurement.
- Excellent stability & consistency of gas column retrievals from C_2H_2 cell demonstrated by COCCON (Alberti et al., 2022; repeatability <0.001%, consistency ~0.002%)!

FTIR open-path measurements

Considerable work has been done on FTIR OP measurements by different investigators, e.g., UoW, UHD, UB, …

Professional OP NIR FTS setup for GHG measurements (Deutscher et al., 2021):

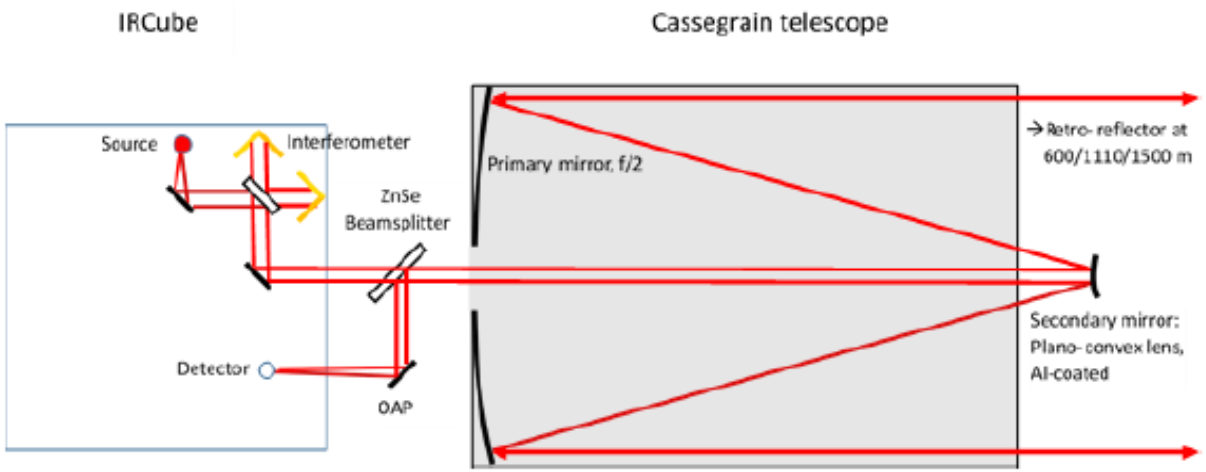
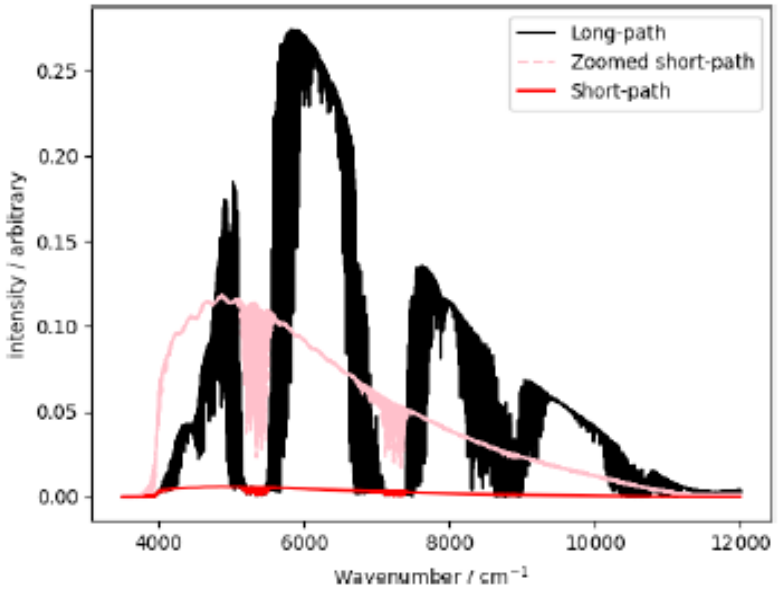


Image: Bruker OPS flyer

FTIR open-path measurements

Results (Deutscher et al., 2021):
2 x 1500 m, 12“ telescope, 60 cm x 62 cm retroreflector array



Gas fitted	Interfering species	Spectral region (cm^{-1})
O_2	H_2O	7790–7960
CO_2	H_2O	4800–5050
CH_4	H_2O	5885–6150
H_2O, HDO	CO_2	4910–5080
CO	H_2O	4260–4310
N_2O	CH_4, H_2O	4300–4460

(T fit performed in CO_2 window)

Measurement period	Instrument setup (path, reflector, telescope)	Signal-to-noise ratio (SNR)	Repeatability (1σ)			
			CO_2 (ppm)	CH_4 (ppb)	CO (ppb)	N_2O (ppb)
1	600 m, gold, 10 in.	2050	0.74	8.5	7.0	8.4
2	600 m, glass, 10 in.	6400	0.60	14.8	24.2	30.9
3	1110 m, glass, 10 in.	3750	0.38	3.8	27.1	35.8
4	1500 m, glass, 10 in.	2300	0.46	3.9	28.5	35.6
5	1500 m, glass, 12 in.	3200	0.28	2.1	17.1	21.8
Ref*	1500 m, quartz, 12 in.	750	1.7	21	–	–

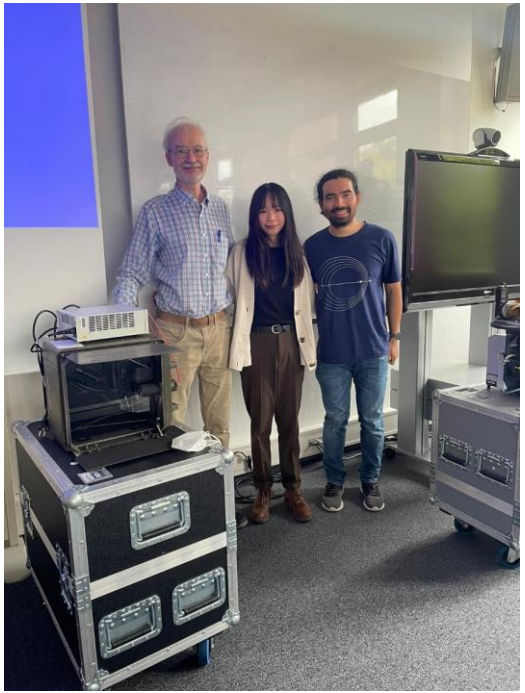
* Deployment at Heidelberg (Griffith et al., 2018).

OP measurements using the EM27/SUN FTS

We decided to use this topic for KSOP master thesis (6 months):

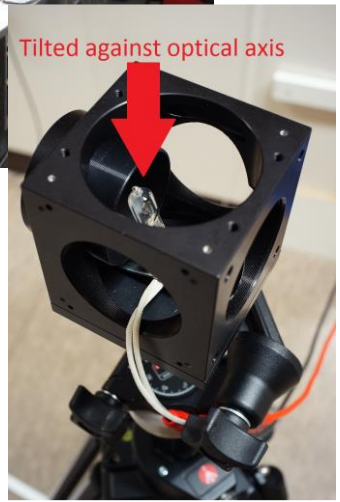
Master student: Uyen Nguyen

Supervisors: C. Alberti, F. Hase
Examiner: J. Orphal



The following material is a condensed version of the contents of her thesis.

OP measurements using the EM27/SUN FTS

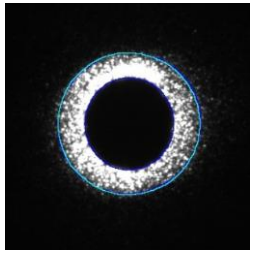


5 cm dia

VIS / IR searchlight
AEG BSW 301
(Leopard / Marder tank)
Off-axis paraboloid
28 x 28 cm^2

OP measurements using the EM27/SUN FTS

Very basic approach, no beam expander, EM27/SUN FTS characteristics:
beam diam 6 mm
FOV 0.27°



5 cm diameter source: 9 m
28 cm diameter source: 58 m

Cons of remote source:
- Optical path equals geometric path (no doubling)
- Power at source location required
- Alignment of source required
- (Signal contribution from scattered sunlight)

Pros of remote source:
+ No short-path signal
+ Much higher signal level than fiber coupling (4x advantage over BS)

OP measurements using the EM27/SUN FTS

Open-path measurements:

- 7th floor of the IMK-ASF Institute (vented)
- Coordinates: 49.094 °N, 8.4336 °E
- 134 m a.s.l (30 m above ground)
- 22 m path length

ICOS reference:

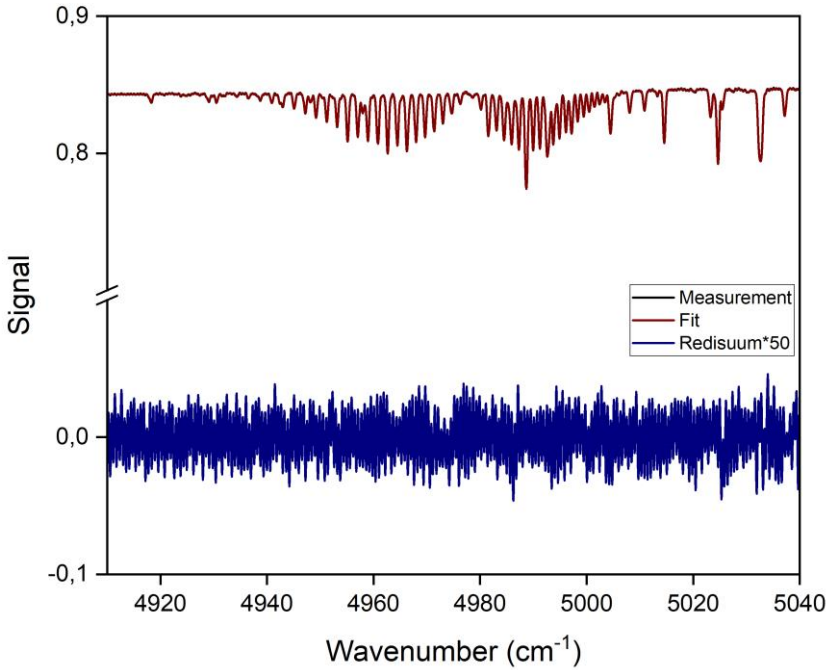
- Cavity ring-down spectrometer (CRDS, Picarro, model G2301)
- Coordinates: 49.092 °N, 8.4249 °E
- 110 m a.s.l (200 m above the ground)
- Measurement levels: **30** / 60 / 100 / 200 m
- Pressure reference (2.5 m above ground)

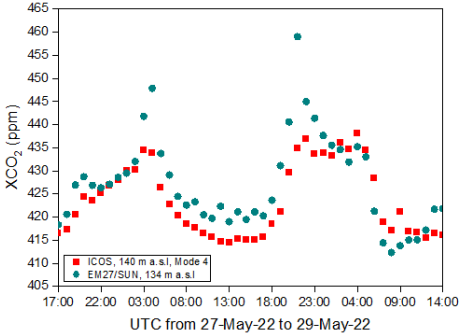
OP measurements using the EM27/SUN FTS

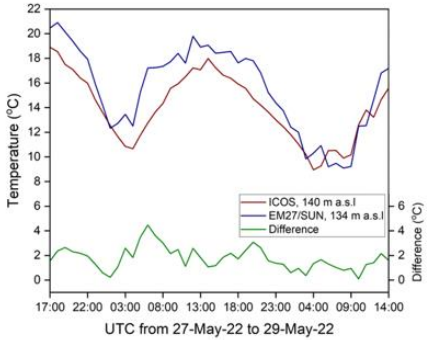
Measurement session 27-29 May 2022 (46 hours)

Precision CO_2 (10 min) ~ 1 ppm

DG, fibre, 3 km: 1 ppm
ND, BS, 3 km: 0.3 ppm
(5 min integration)

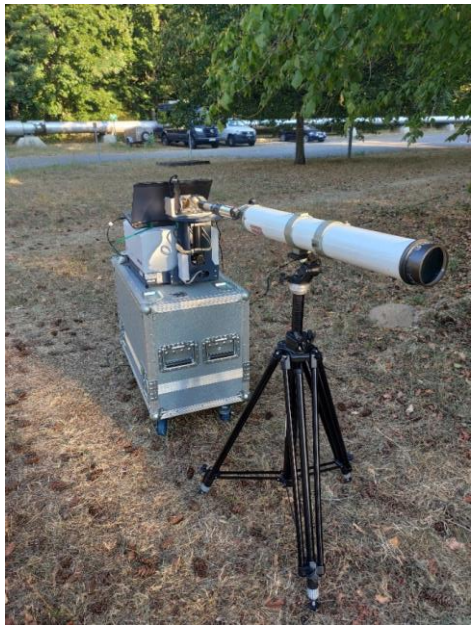




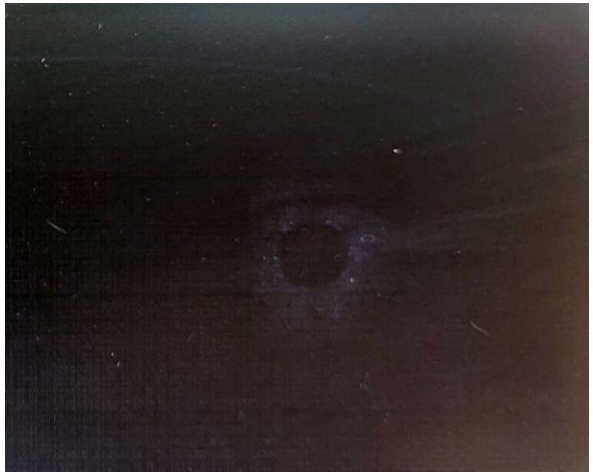


OP measurements using the EM27/SUN FTS

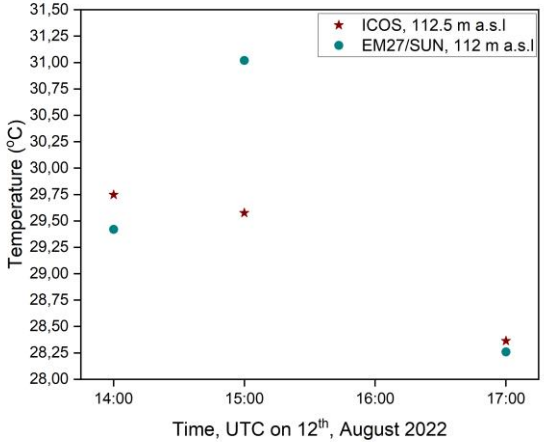
Demonstration of improvised beam expander: 80 mm free diameter, 8x magnification
28 cm diameter source: up to 390 m (used: 115 m)

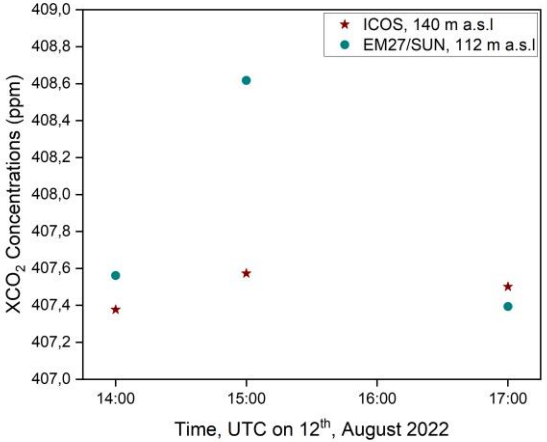


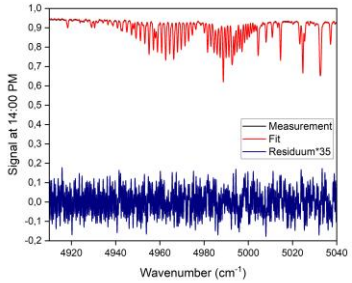
Note: solar tracker can be used for fine alignment!

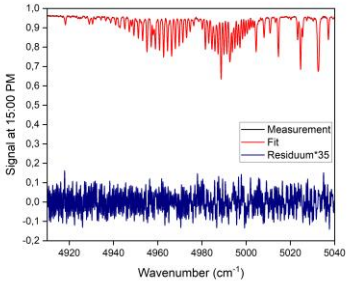


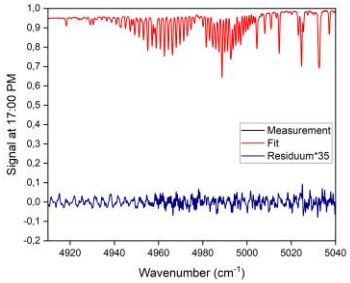
OP measurements using the EM27/SUN FTS











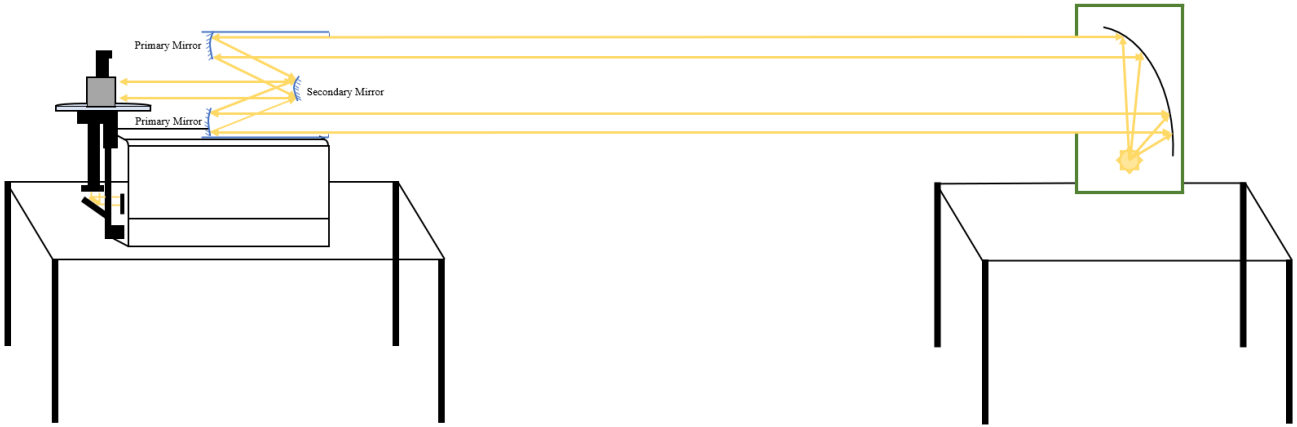
Note channeling in spectral residuals:

Lens telescope with VIS AR!

OP measurements using the EM27/SUN FTS

Outlook: use larger Cassegrain beam expander, e.g. 30x magnification
(~ 20 cm diameter required, ~ 1kEUR)
28 cm diameter source: up to 630 m
50 cm diameter source: up to 2.0 km

(~ 1 km required for measuring CH_4, factor ~ 50 weaker)



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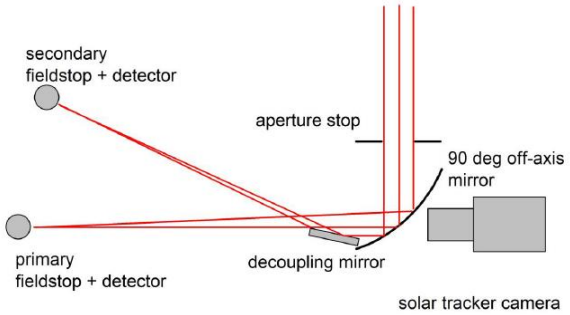
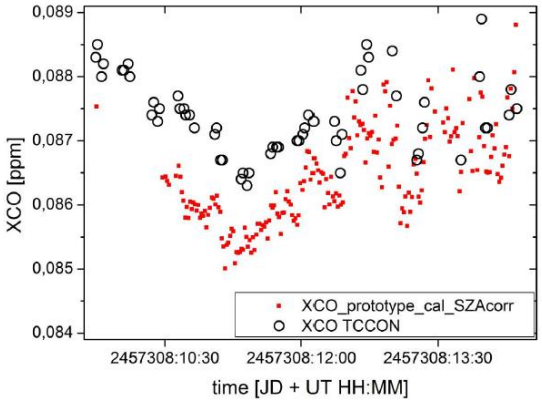
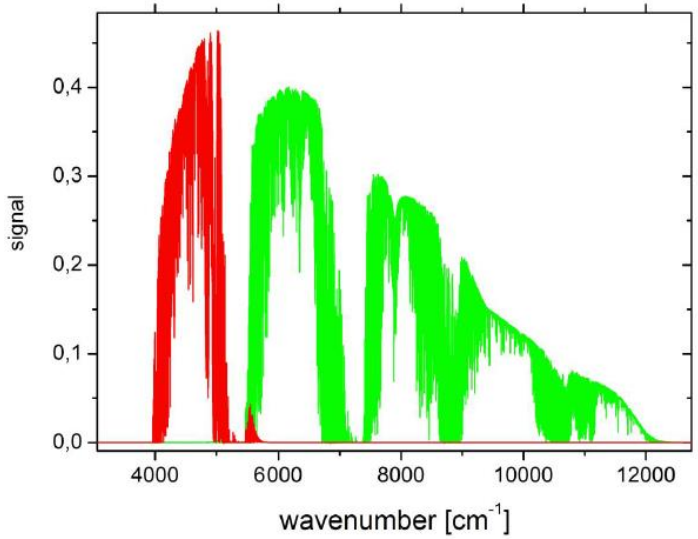
Jochen Groß
Benedikt Herkommer
Matthias Schneider
Qiansi Tu (Tongji Univ.)

+ external COCCON collaborators!

CO channel extension







F. Hase et al."Enhancing the capabilities of a portable FTIR spectrometer for greenhouse gas measurements…“ , AMT, 2016