# FRM4GHG 2.0
# Fiducial Reference Measurements for Greenhouse Gases


## Semester Report Month T0+6

| | |
|---|---|
| **Deliverable:** | **D4.1.3** |
| **Date:** | **06/04/2022** |
| **Lead authors:** | **Justus Notholt, Mahesh Kumar Sha and Martine De Mazière** |
| **Subject:** | **ESA-Contract No. 4000136108/21/I-DT-lr** |
| **Category:** | **ESA Express Procurement (EXPRO)** |
| **Our ref.:** | **Proposal, FRM4GHG 2.0 – Expro, ESA RFP/3-17031/21/I-DT-lr, revision from 27 August 2021 and 7 September 2021** |

# Table of contents

# 1 DOCUMENT CHANGE RECORD

| Issue | Date | Item | Comment |
|---|---|---|---|
| V1.0 | 2022-04-17 | - | Initial version |
| | | | |
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| | | | |
| | | | |

# 2 ACCESS LIST

This document is a deliverable "D4.1.3: Semester report Month T0+6 created for the project FRM4GHG 2.0 and will be submitted to ESA. The document can be downloaded from the project webpage http://frm4ghg.aeronomie.be.

# 3 PURPOSE

The document describes the progress of the WPs.

# 4 DOCUMENT STRUCTURE

The document gives the Power-Point-Files of the presentations for all partners. The presentations were shown at the regular monthly telecom on April 6 2022. These presentations form the deliverable of the semesterly reports 4.1.3. including technical sections about the progress in WPs 1 to 3.

# 5 RESULTS

All WPs of FRM4GHG-2 make good progress. The talks were given in the following order:

1. University of Bremen, Germany
2. Royal Belgian Institute for Space Aeronomy, Belgium
3. Finnish Meteorological Institute, Finland
4. University of Wollongong, Australia
5. Karlsruhe Institute of Technology, Germany
6. Rutherford Appleton Laboratory, Great Britain
7. University of Groningen, Netherland

# 6 APPLICABLE DOCUMENTS

Statement of Work: Fiducial Reference Measurements for Ground-Based IR Greenhouse Gas Observations (FRM4GHG 2.0)
Prepared by: EOP-GMQ, Reference: ESA-EOPG-EOPGMQ-SOW-21

# 7 REFERENCE DOCUMENTS

# Progress report Bremen

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Winfried Markert

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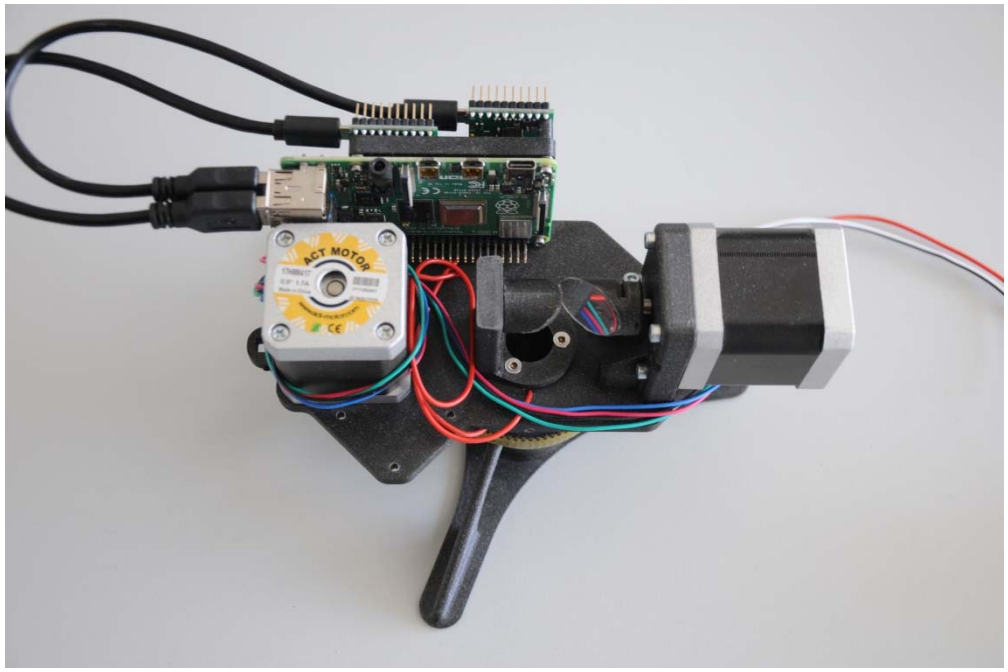
https://frm4ghg.aeronomie.be/

# Objective 1

**Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations (FRM4GHG 2.0)**

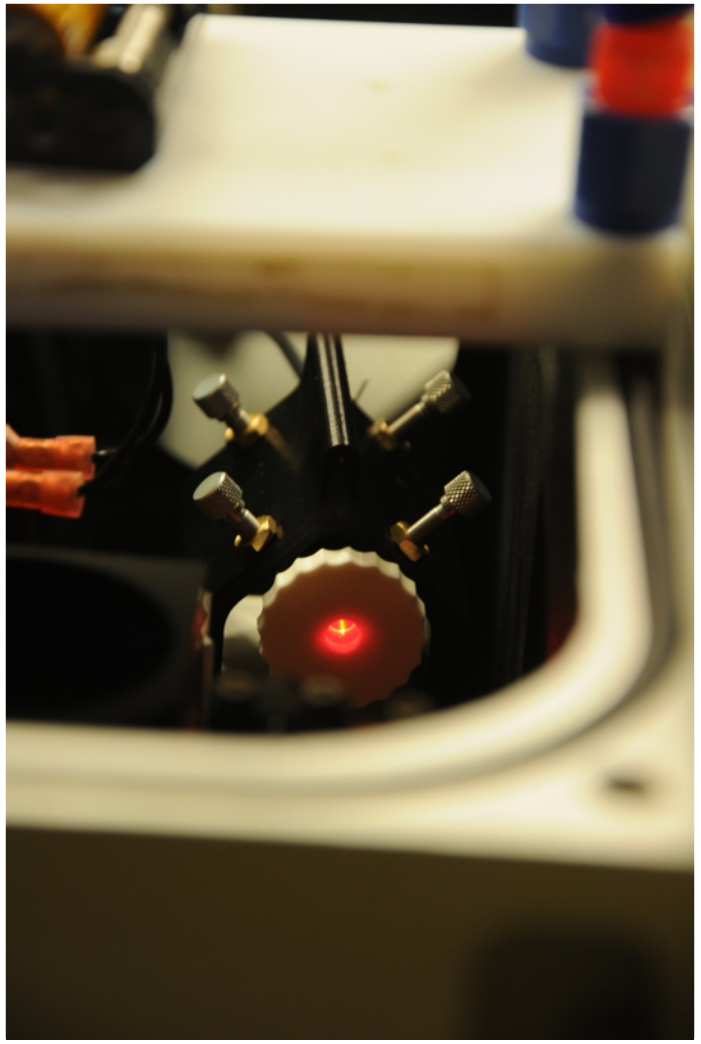
- **WP1 T1: Development of a compact solar tracker**
  - A prototype of a compact solar tracker has been built using parts printed with a 3D printer.
  - Further development will be discussed with BIRA.



# Objective 2

**Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations (FRM4GHG 2.0)**

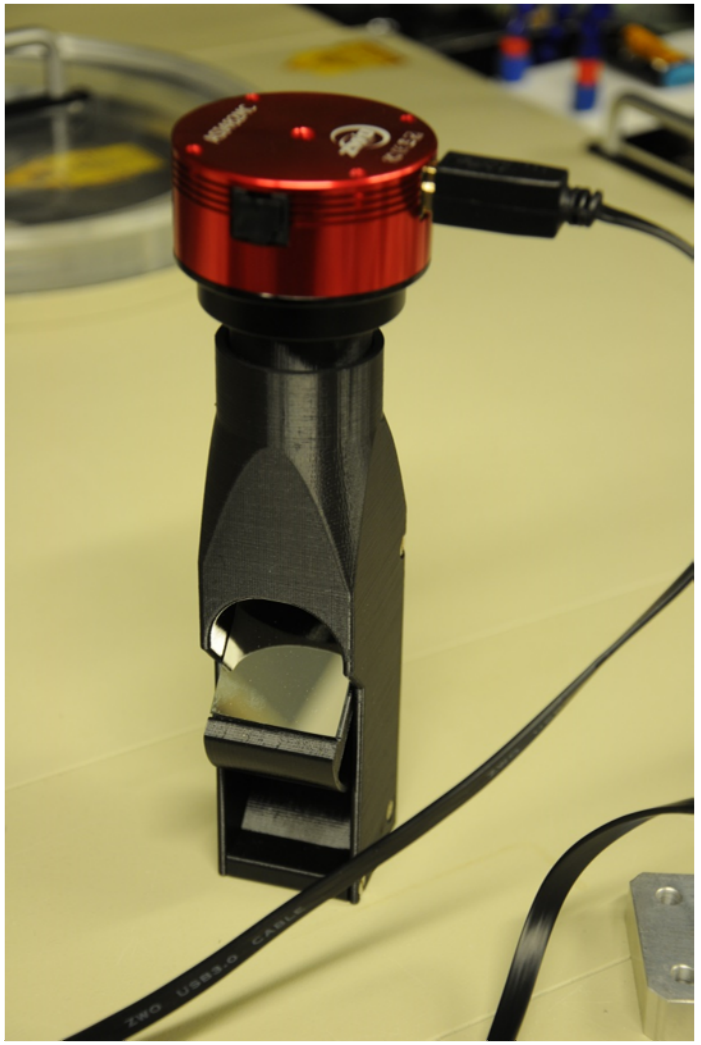
- **WP1 T3: Further development of alignment tools**
  - An adjustable holder for the alignment laser has been created to place the laser before the incoming aperture of the FTIR spectrometers. The holder is adjustable for the x- and y-direction and the parallel offset. One can see the back reflection from the laser, reflected on the internal spectrometer mirror, which must be centred on the white screen in front of the alignment laser. This item has been printed using a 3D printer.



# Objective 2



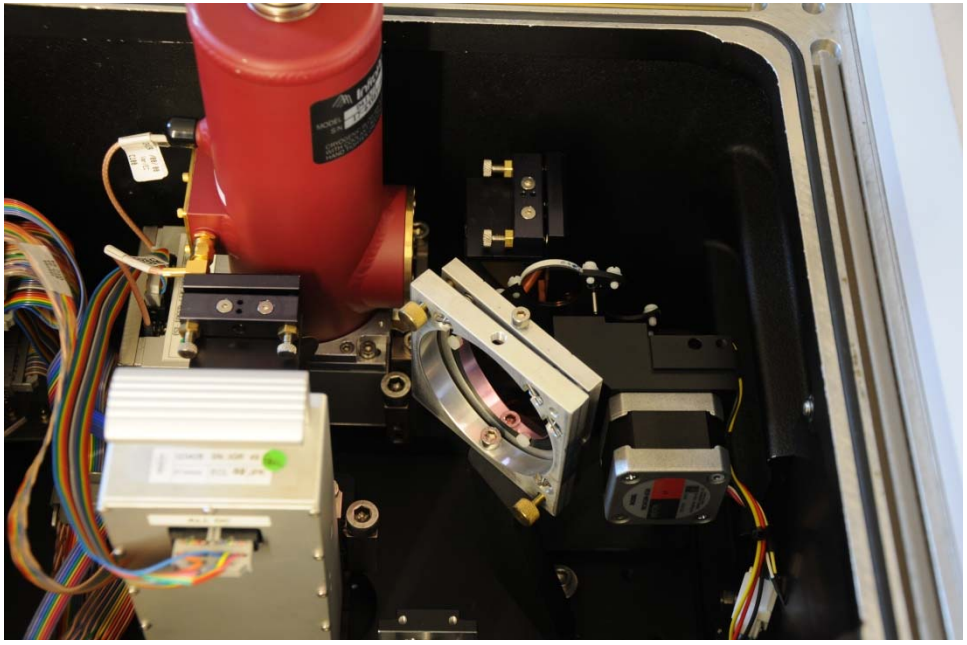
- **WP1 T3: Further development of alignment tools**
  - An astronomical camera for the alignment with a larger detector die (12.7 mm diameter) has been purchased to be able to picture also bigger apertures.
  - A camera holder has been created to place the camera in the outgoing light path of the FTIR spectrometers. The camera holder is adjustable for the angle of incoming light and the focus of the camera. This item has been printed using a 3D printer.



# Objective 3

**Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations (FRM4GHG 2.0)**

- **WP2 T3: Simultaneous measurements in NIR (InGaAs detector) and MIR (InSb detector) spectral domains**
  - A test setting has been installed in Bremen. The setting of the detector chamber has been reconstructed. The InGaAs and the InSb detector have been connected to be able to measure simultaneously in AC or DC mode. A 50:50 beam splitter has been installed to split the light for the two detectors. In front of the InSb detector, a 5 plc. Filter wheel has been installed.
  - Test measurements and corresponding retrievals will be performed in Bremen within the next weeks. The same setup will be adapted to Nicosia (Cyprus) after successful tests.



# *Thank you for your attention*

# BIRA-IASB progress in WP 1 – 4 during Oct 2021 – Mar 2022

BIRA-IASB team – Mahesh Kumar Sha*, Martine De Mazière, Sophie Berkenbosch, Pepeijn Cardoen, Filip Desmet, Christian Hermans, Lars Jacobs, Nicolas Kumps, Corinne Vigouroux, Minqiang Zhou

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**WP 1: Instrumental improvements to low-resolution spectrometers for GHG observations**

Contractor: UBremen

WP Manager: **UBremen**

Start Event: Month 1 Planned Date: September 2021
End Event: Month 48 Planned Date: September 2025

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**Inputs:**

- EM27/SUN, Vertex70, IRcube and LHR in their final configurations assessed in the FRM4GHG projects Phases 1 and 2
- All results of FRM4GHG-1

**Tasks** (Responsible partners; lead in bold):

**T1** (**BIRA**, UBremen, UoW, KIT):

Develop a more mobile, stand-alone version of the Bruker Vertex70 instrument for deployment in the field. The envisaged adaptations are:

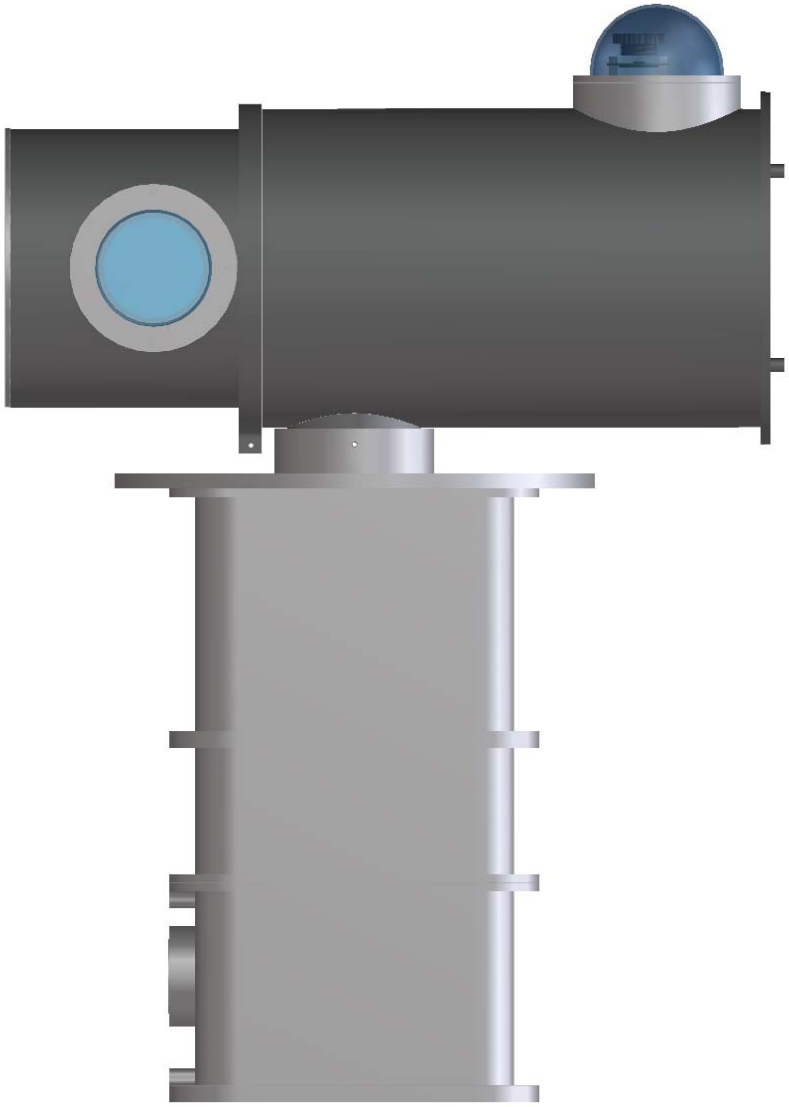
- Embedding the Vertex spectrometer in a thermally isolated, waterproof enclosure, including a rain sensor and compact solar tracker mounted to the spectrometer, and an automatically controlled cover of the tracker.
- Testing the use of an alternative detector to replace the Liq. N2 cooled InSb detector (e.g., TE-cooled MCT detector).

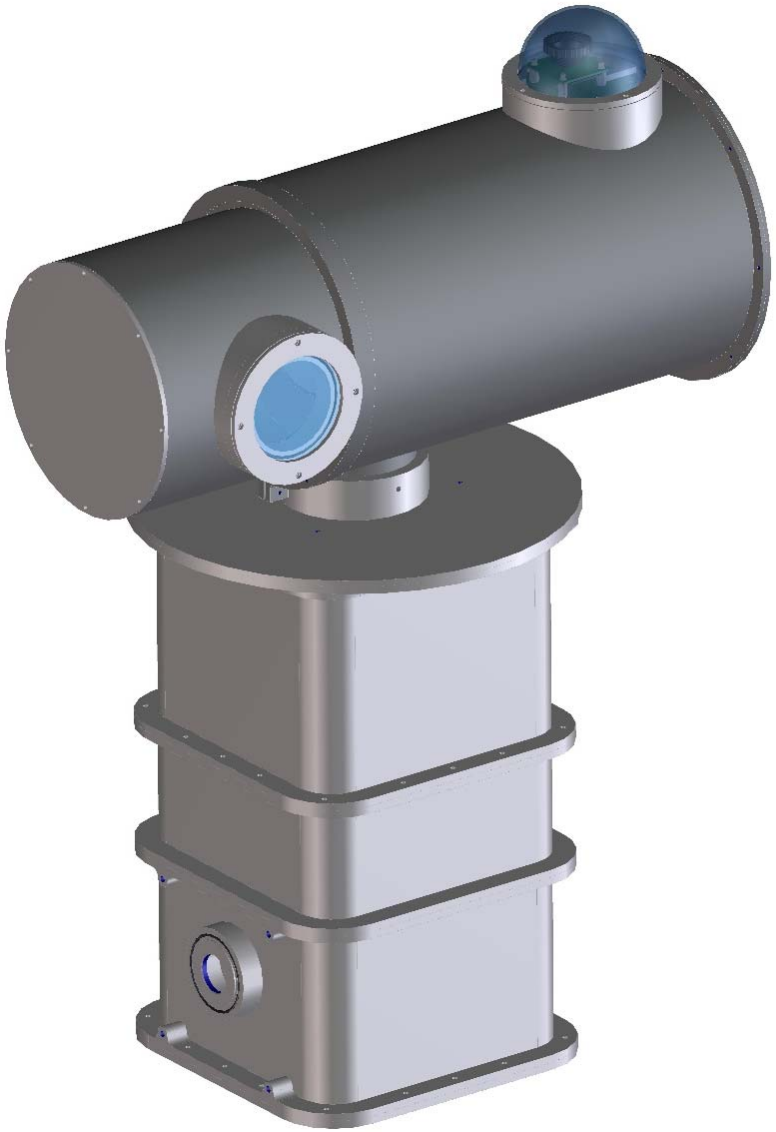
**Current situation and planned work for the short term:**

Status – BIRA-IASB

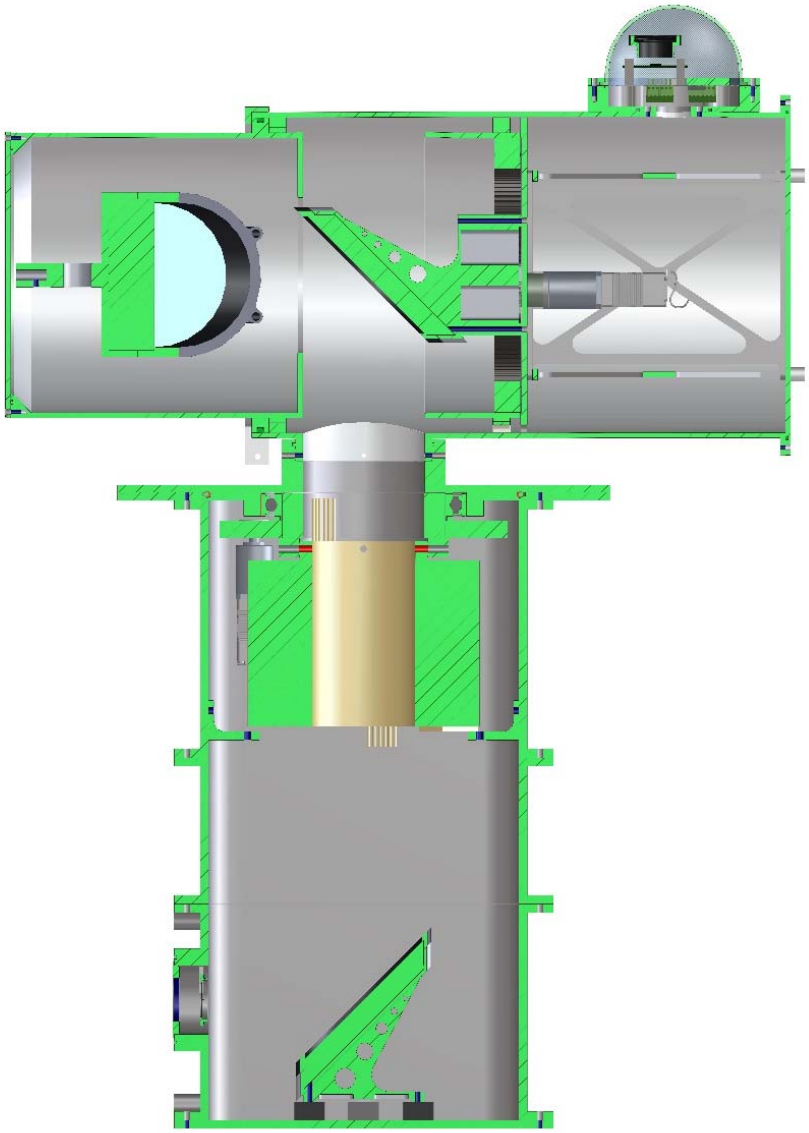
- Design and testing of components of the compact solar tracker is ongoing

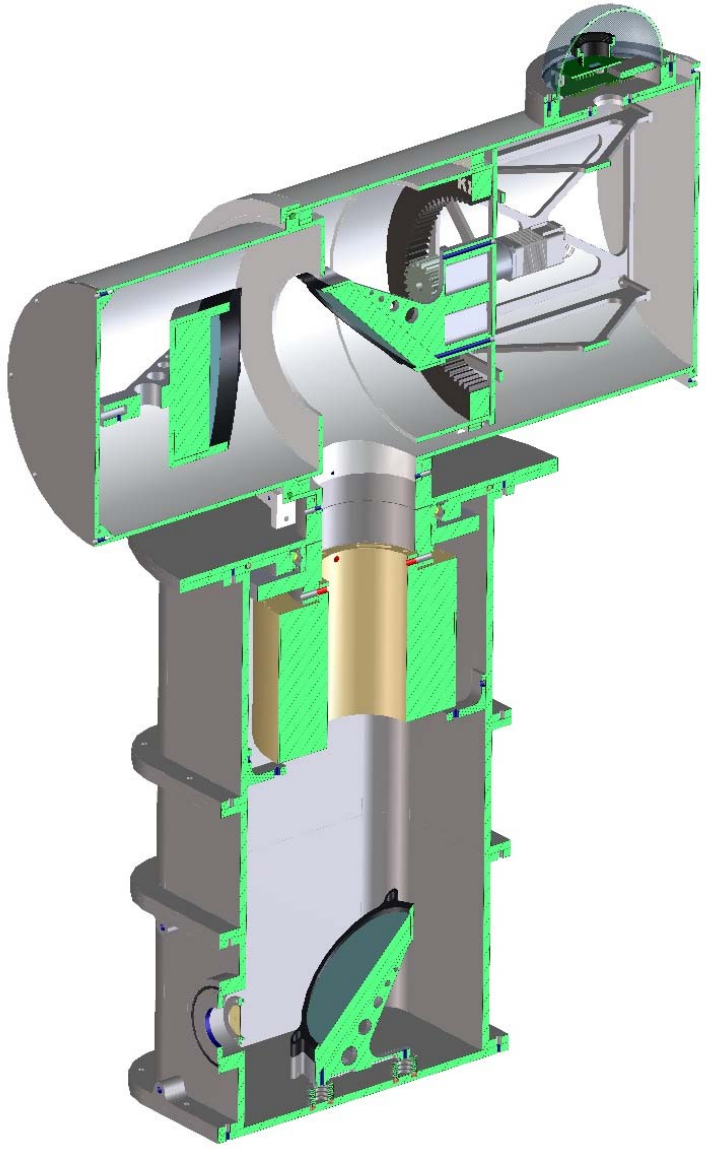
# Mechanical Design of compact solar tracker



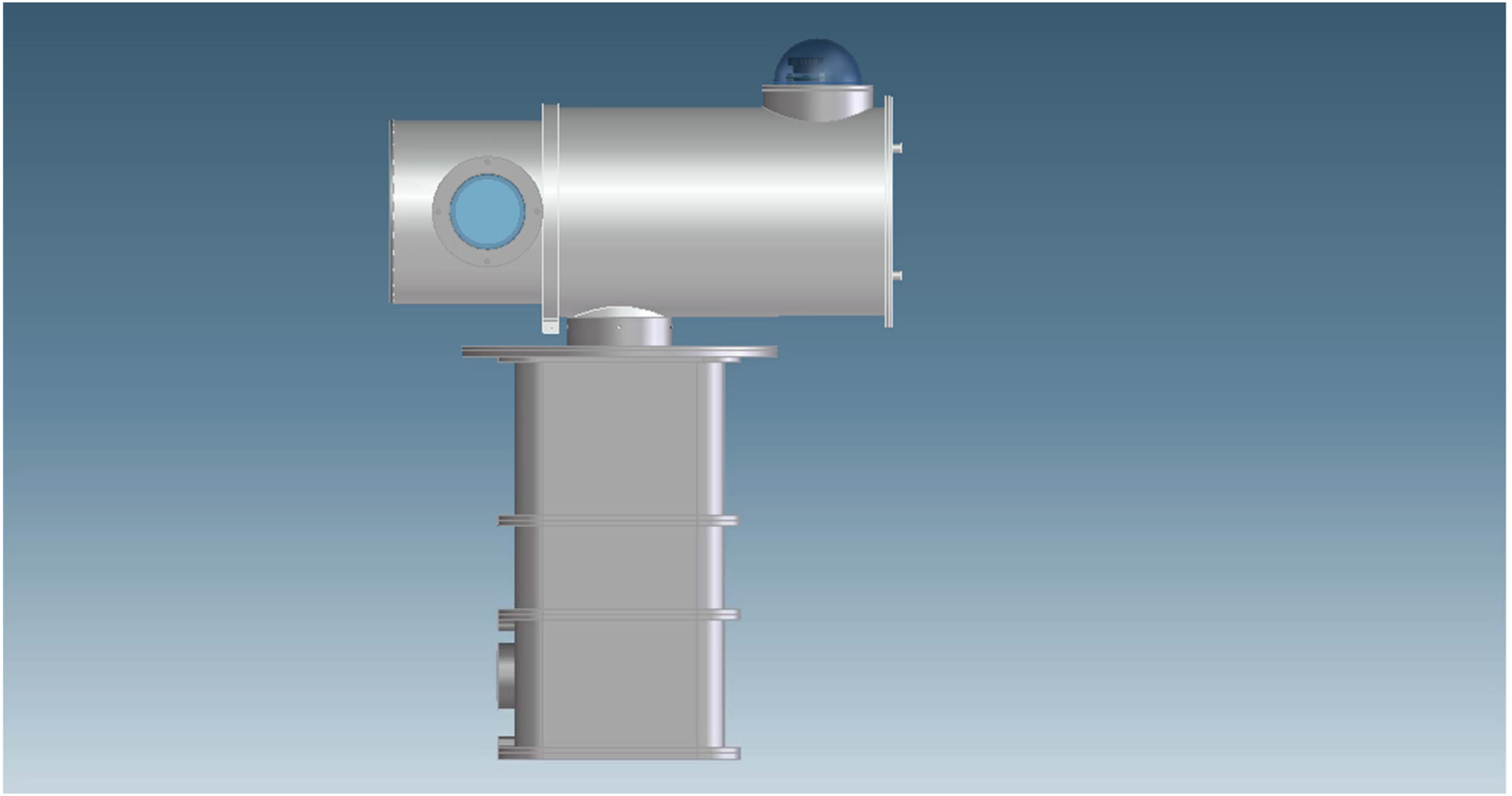


# Mechanical Design of compact solar tracker





# Mechanical Design of compact solar tracker



# WP2: Improvements to retrieval algorithms for GHG and additional species from low-resolution and TCCON spectrometers

**T3 (UBremen**, BIRA, UoW, FMI, KIT):

Further development of GHG profiling using NIR and MIR spectra, for $CO_2$, $CH_4$, CO and $N_2O$

- Perform (quasi-)simultaneous measurements in NIR (with InGaAs detector) and MIR (with InSb detector) spectral domains at Cyprus, Wollongong, Sodankyla, Karsruhe and St Denis/La Réunion. 'Simultaneous' points to InSb measurements at TCCON standard resolution (0.02 $cm^{-1}$); 'quasi- simultaneous' points to InSb measurements at NDACC standard resolution with the TCCON instrument. (All)
- Develop strategies for profile retrieval of the target GHG, and determine spectral resolution that enables retrieval of partial column information for the target GHG gases:
  - $CH_4$ (BIRA):
    - optimise $CH_4$ profile retrieval from standard TCCON NIR spectra (using SFTI4NIR);
    - investigate $CH_4$ profile retrieval from the InSb MIR spectra recorded simultaneously with the standard TCCON measurements, i.e., at the standard TCCON spectral resolution of 0.02 $cm^{-1}$
    - investigate to what extent $CH_4$ partial column information can be retrieved from the low-resolution spectrometer data in the NIR and MIR spectral domains (0.2 to 0.5 $cm^{-1}$).
  - CO (UBremen):
    - verify improved CO column retrievals from the NIR TCCON spectra (with GGG) using vertical profile information from the MIR spectra (retrieved with SFIT4, at TCCON and NDACC resolutions).
    - investigate the feasibility of retrieving CO from the low-resolution (Vertex) spectrometers in the MIR domain
  - $N_2O$ (UBremen):
    - Investigate the possibility of retrieving the $N_2O$ tropospheric column from standard TCCON spectra
- Validate these 'enhanced' retrieval products using collocated independent data (e.g., available AirCore or aircraft data, in-situ data, …) (BIRA for $CH_4$, UBremen for CO and $N_2O$)

**Current situation and planned work for the short term:**

Status – BIRA-IASB

$CH_4$ & $N_2O$ retrieval from Bruker Vertex70 and mid-infrared spectra from Bruker IFS 125HR at Sodankylä – for details see slides presented during the meeting on 17 November 2021 and publication submitted to AMT with title "Atmospheric N2O and CH4 total columns retrieved from low-resolution FTIR spectra (Bruker Vertex 70) in the mid-infrared region"

# WP2: Improvements to retrieval algorithms for GHG and additional species from low-resolution and TCCON spectrometers

**T4a** (**BIRA**, UoW):

Optimize retrieval of HCHO for low-resolution instruments (Vertex70, HR125LR) that include measurements in the MIR spectral domain.

**T4b (UBremen)**

Investigate feasibility of retrieving OCS from the low-resolution MIR spectra using SFIT4.

**T5** (**FMI**, RUG):

- Perform additional AirCore launches during the 4 years of the project to have enough statistical coverage
- Improve retrieval of CO and $CH_4$ profiles in the stratosphere from AirCore measurements based on dual launches and LISA launches at Sodankyla.
- Reprocess all 2017-2019 Aircore data at Sodankyla

**T6** (**BIRA**, KIT, UBremen, UoW, FMI, RAL):

Update FRM4GHG dataset based on latest version of PROFFAST and GGG.

- All partners will re-process their own data with latest version of GGG / PROFFAST/ LHR retrieval algorithm
- BIRA will re-do the intercomparison exercise to validate the results.

**Current situation and planned work for the short term:**

Status – HCHO – BIRA-IASB – Vertex70 setup at Uccle (BIRA campus), liquid nitrogen ordered, waiting for good weather to perform measurements with the InSb detector.

**WP 3: Improvements to TCCON and COCCON network operations, consistency and data delivery**

Contractor: UBremen

WP Manager: **KIT**

| | |
|---|---|
| Start Event: Month 1 | Planned Date: September 2021 |
| End Event: Month 48 | Planned Date: September 2025 |

**Inputs:**

- GGG2020 with updated TCCON a priori profiles
- Prototype EM27/SUN travelling standard instrument
- Agreement with ECMWF for facilitating delivery of ECMWF/CAMS data

**Tasks** (Responsible partners; lead in bold):

**T1** (**BIRA**, KIT, UBremen):

Develop rapid delivery of GHG data for satellite validation from low-resolution NIR spectra:

- Establish and implement procedure for procuring NRT ECMWF P/T profiles and providing them to partners
- Implement dual option to either use NCEP or NRT ECMWF P/T profiles in PROFFAST
- Verify the improvements of the retrieval products using the updated TCCON a priori profiles in PROFFAST
- Investigate the benefits of using CAMS data provided by ECMWF as a priori profiles for the target gases in PROFFAST
- Coordinate with TCCON chairs and GGG developers for using NRT ECMWF P/T profiles in GGG
- Plan and implement, for Vertex70 and IRCube, all the proper actions and procedures aimed at pursuing harmonisation with COCCON

**Current situation and planned work for the short term:**

Status
3.1.1 – ECMWF P/T profiles (ERA5 – reanalysis*) will be provided for the target TCCON / COCCON, latency of 5 days, monthly files are available on 6th of every month, lat-lon 0.25 degree, 37 pressure levels (1000 hPa to 1 hPa) – BIRA-IASB
3.1.2 – KIT
3.1.3 – BIRA-IASB
3.1.4 – CAMS (O-suite – changes in time with model updates, **reanalysis** – stable in time, produced using 4DVar data assimilation in Cycle 42r1 of ECMWF's Integrated Forecasting System (IFS), with 60 hybrid sigma/pressure (model) levels in the vertical, with the top level at 0.1 hPa, 3-hourly, 3-dimensional, time-consistent atmospheric composition daily means or monthly means of daily means for the month as a whole, CO2, CH4, CO data, public data till 2020, private data to be discussed
3.1.5 – UBremen
3.1.6 – UBremen, UoW, KIT
COCCON plan for Vertex and IRCube yet to start.

*https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-pressure-levels-monthly-means?tab=overview

**T2a (BIRA,** all partners)
Outreach:

- Throughout the whole project duration: regularly update FRM4GHG Webpages including internal documents repository (building upon FRM4GHG-1 Website); track communications/ publications including results from the project
- Coordinate/ monitor involvement in Sentinel validation efforts

**T2b (BIRA,** all partners)
Disseminate FRM4GHG-2.0 dataset (see D4.2.3) and PROFFAST source code via Webpages; the FRM4GHG-2.0 relevant datasets will also be made available to the ESA Validation Data Centre (EVDC) in GEOMS HDF

**Current situation and planned work for the short term:**

Status – BIRA-IASB

**D4.2.1 Dynamic FRM4GHG Website** (BIRA, continuously)
**D4.2.2 Technical Report about Sentinel validation results using FRM4GHG-2.0 data** (BIRA, continuously)
**D4.2.3 Provision of FRM4GHG-2.0 datasets** (BIRA, M48)
Dissemination of all measurement data [Level 1] and corresponding retrieved data [Level 2] collected during the project, as well as of all re-processed (during the project) datasets [Level-2], including a Digital Object Identifier DOI, through the EVDC [RD-9] in GEOMS HDF format [RD-10] as well as through the FRM4GHG project webpages.

frm4ghg.aeronomie.be website update of several pages

Twitter: #frm4ghg
Link to @ESA_EO, @CopernicusEU, @Sentinel5P, …

Write on Campaign Blog

Update pictures on website from campaigns, instrument development, site visits of traveling standard, team meetings, conference / workshop presentations, …

# *Thank you for your attention*

# FMI progress in WP 1 – 3 during Oct 2021 – Mar 2022

Rigel Kivi, Pauli Heikkinen, Finnish Meteorological Institute
Huilin Chen, Groningen University

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https://frm4ghg.aeronomie.be/

# Objectives

**Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations (FRM4GHG 2.0)**

FMI:

- Develop AirCore
- Simultaneous NIR and MIR spectra recording with TCCON instrument at Sodankyla
- Perform additional AirCore launches
- Update FRM4GHG dataset based on latest version of PROFFAST and GGG
- Project management (contributor)
- Outreach (contributor)

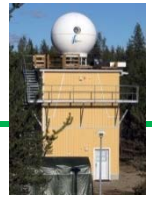
# Measurements

**Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations (FRM4GHG 2.0)**

FMI:
We have started FRM4GHG 2.0 measurements at Sodankylä: TCCON, AirCore, etc.
Possibility to host visiting instruments and field campaigns.



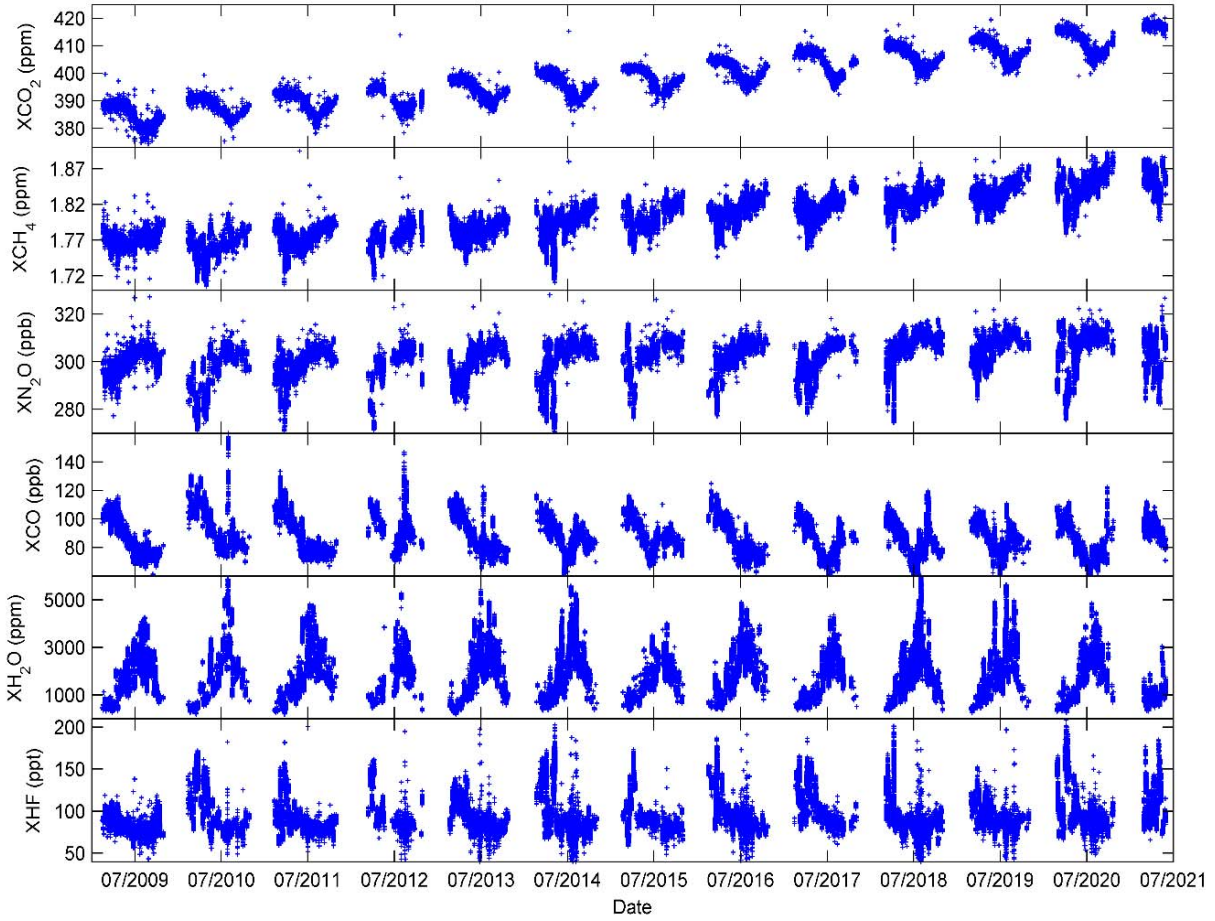
# TCCON



Bruker *IFS 125HR* with *A547N* solar tracker.
Detectors:
*RT-InGaAs:* *12800 - 4000 cm$^{-1}$*
*RT-Si:* *25000 - 9000 cm$^{-1}$*
*LN-InSb:* *10000 - 1850 cm$^{-1}$*

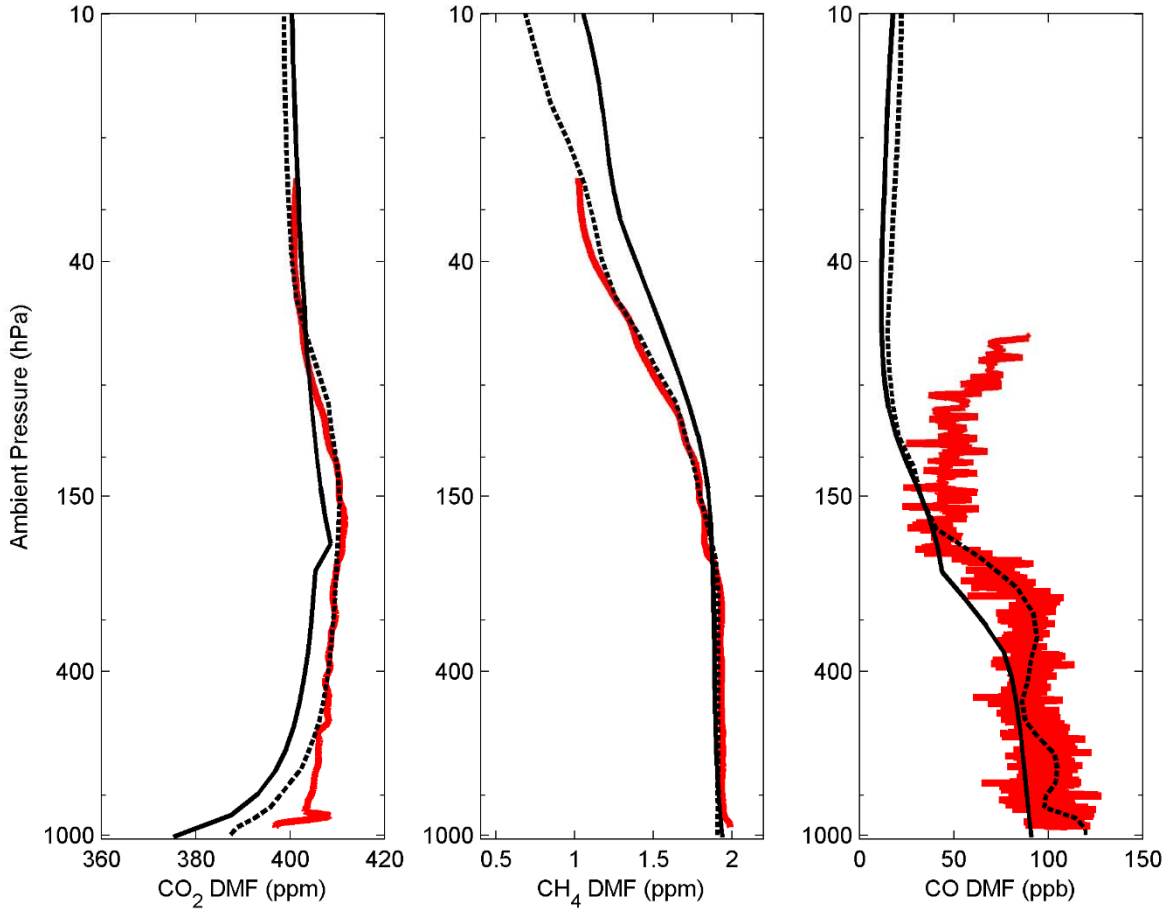
In operation since FEB-2009


Map of the TCCON sites




Column-averaged dry air mole fractions at Sodankylä since 2009. Updated from Kivi and Heikkinen (2016).

# AirCores




AirCore profiles (red), GGG2014 (solid line), GGG2020 (dashed line).
Sodankylä 19 August 2020 07:22 UTC.

# Summary and outlook

Summary:

- AirCore development work is ongoing, preparations are being made to perform first $N_2O$ measurements.
- AirCore flights have ben performed before the KO. Comparison with GGG prior profiles was made for the AirCore flights performed in 2020-2021. Found improved agreement with TCCON priors.
- TCCON retrievals using the latest GGG version were made.
- TCCON instrument is operational. We take both HR and LR measurements. We performed alignment in February 2022, also replaced one of the tracker mirrors. There was an issue with solar tracker hatch motor. We repaired the motor and also ordered a new one. Delivery times are much longer than expected (20 weeks for a motor). Manual hatch operation is a backup. We have FTIR measurements, though need to open and close the cover manually.
- Readiness to host visiting instruments and campaigns.

Outlook:

- AirCore flights are planned for the upcoming 6 month period.
- NIR and MIR spectra recordings.
- Update the FRM4GHG dataset.
- Host visiting instruments.

# *Thank you for your attention*

Photo: Sodankylä site in March 2022.

# Progress Report - Wollongong

Nicholas Jones*, David Griffith, Nicholas Deutscher

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https://frm4ghg.aeronomie.be/

# Objectives

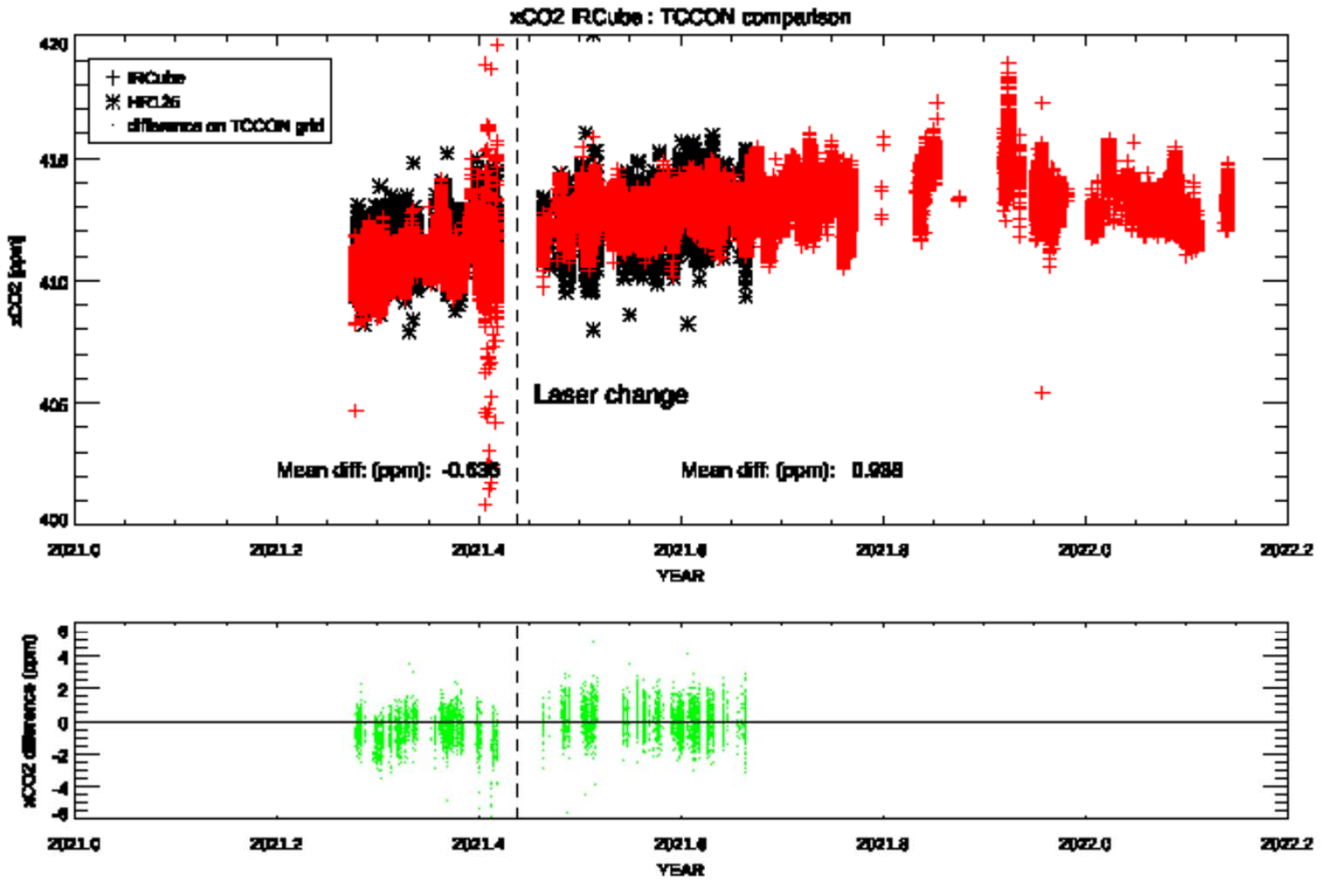
**Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations (FRM4GHG 2.0)**

- Analysis of IRcube spectra 2021-2022 (NJ)
- First EM27 solar spectra with fibre-optic-coupled telescope and tracker (DG)
  - Initial spectra
  - Tracker updates
- MIR operation of IRcube with TE-MCT detector and CaF2 BS (DG)
  - No progress
- Aircore campaign 2022 (NJ, DG, ND)
  - Alice Springs, Central Australia (dry, high albedo, M-gain satellite measurements)
  - Aircore (with NOAA), IRcube, EM27-SUN
  - August 2022 ??

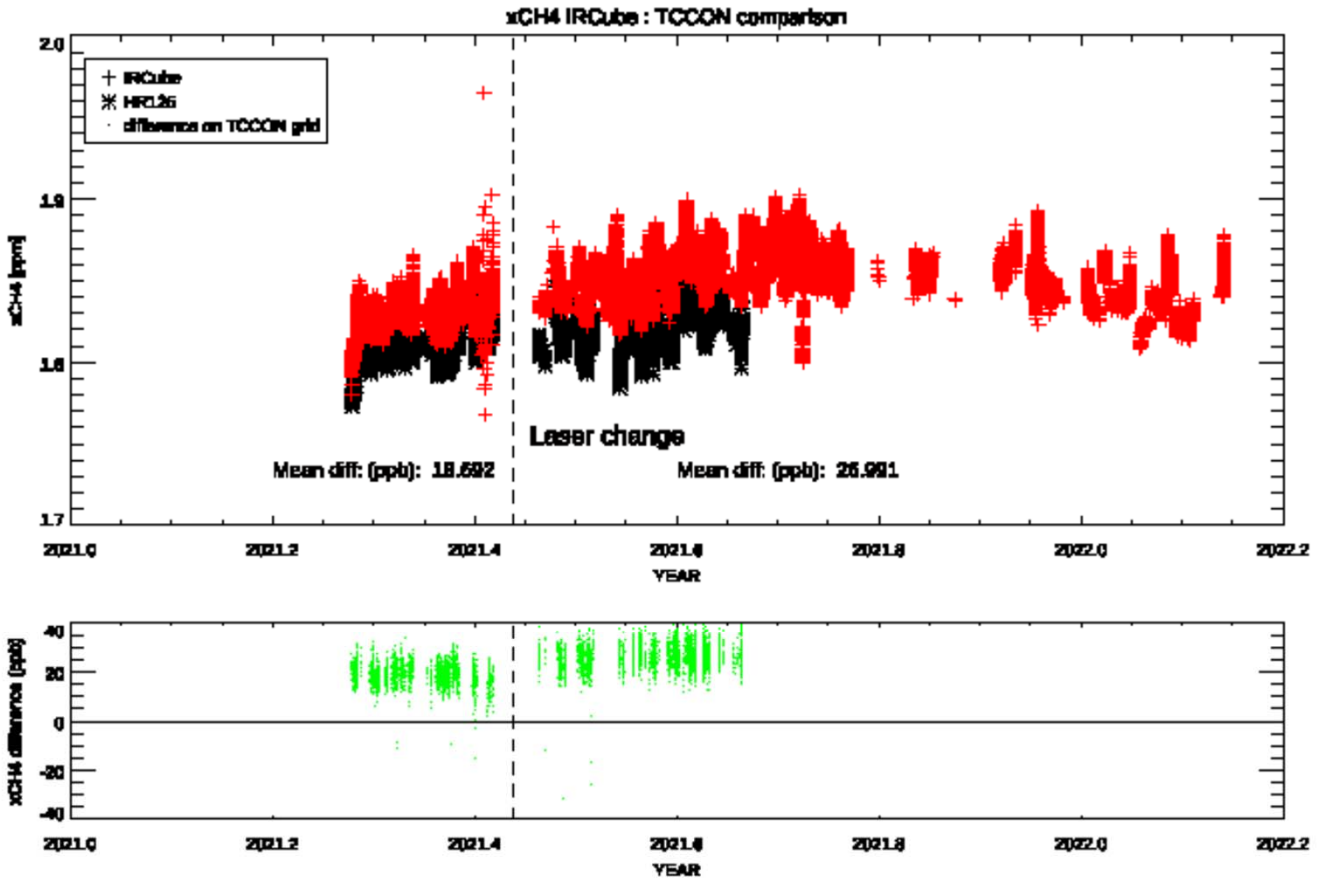
# Initial Analysis of the 2021-2022 IRCube data

- Spectra analysed with GGG2012
- The dependent and independent airmass factors for CO2 were adopted from GGG2020, while for CH4, and H2O not changed from GGG2012
- The section criteria used in all cases were sza less than 80 degrees, xair between 0.98 and 1.02 and GGG flag settings of 0 and 7.
- For comparison, the data shown when TCCON results are available, the IRCube data is interpolated onto the TCCON time grid.
- The “official” TCCON output is used.

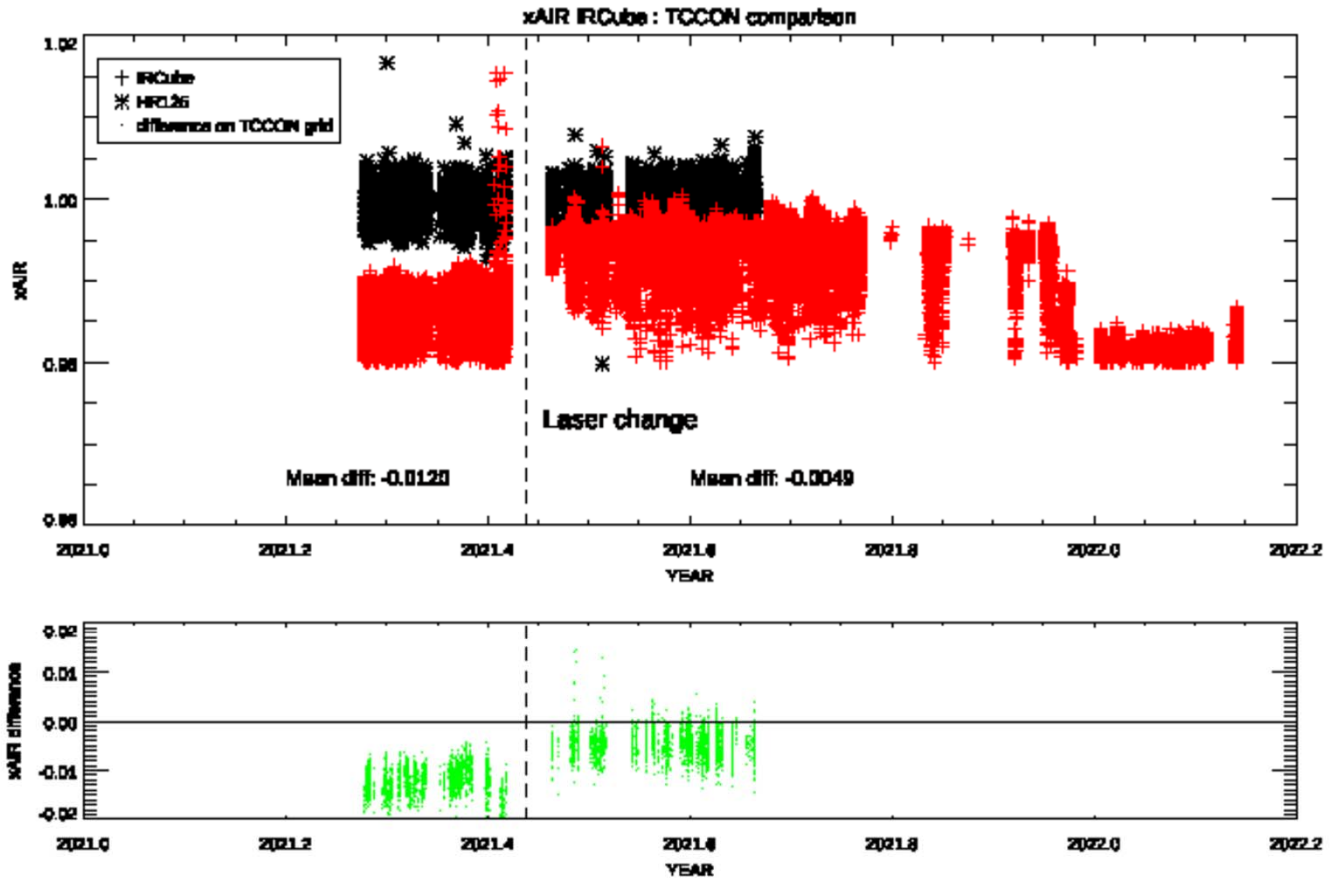
# xCO2


xCO2 IRCube : TCCON comparison
IRCube
HR126
difference on TCCON grid
Laser change
Mean diff: (ppm): -0.635
Mean diff: (ppm): 0.958
xCO2 [ppm]
xCO2 difference (ppm)
YEAR
2021.0
2021.2
2021.4
2021.6
2021.8
2022.0
2022.2

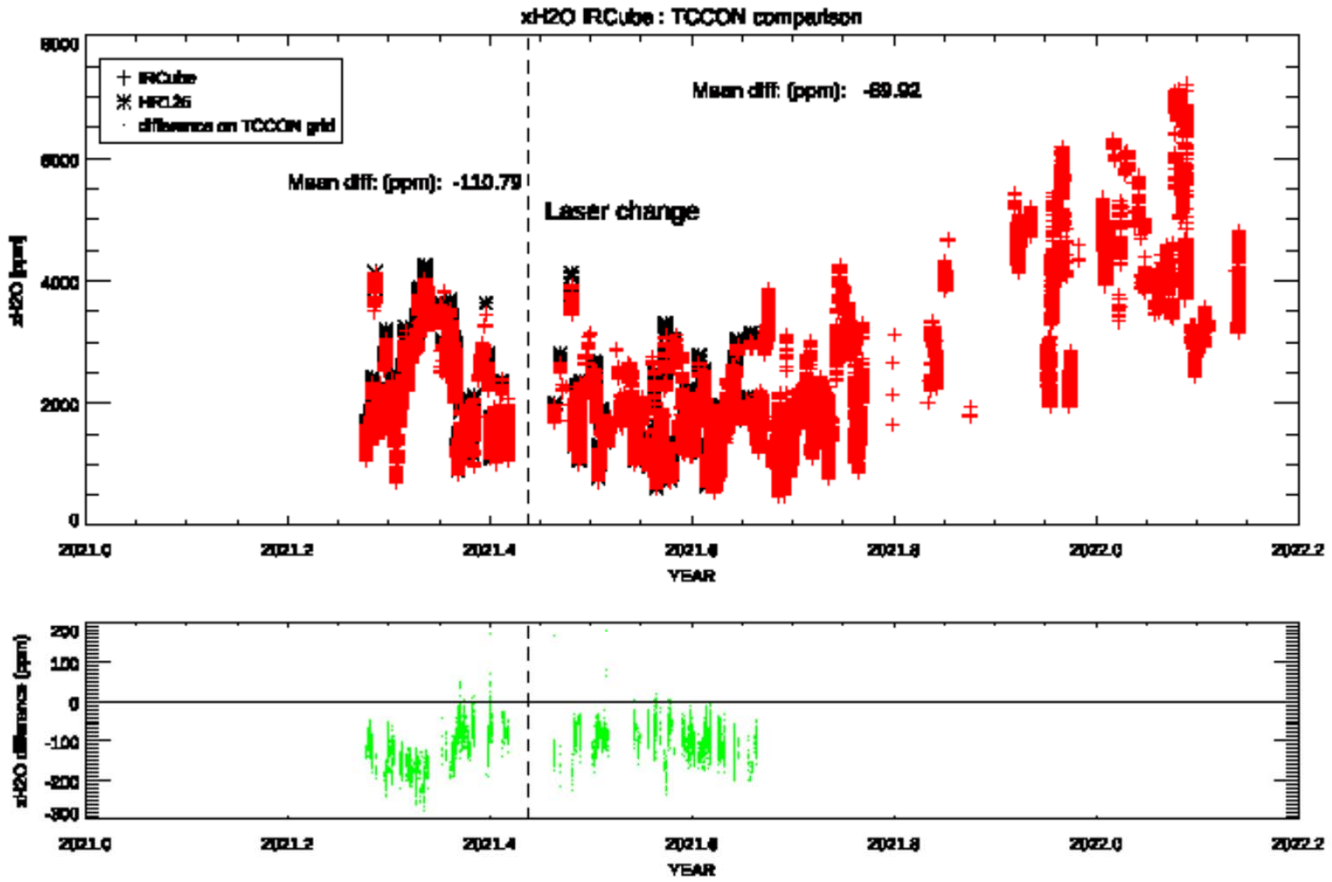
# xCH4


xCH4 IRCube : TCCON comparison
IRCube
HR126
difference on TCCON grid
xCH4 [ppm]
2.0
1.9
1.8
1.7
Laser change
Mean diff: (ppb): 18.692
Mean diff: (ppb): 26.991
2021.0
2021.2
2021.4
2021.6
2021.8
2022.0
2022.2
YEAR
xCH4 difference (ppb)
40
20
0
-20
-40

# xAIR


xAIR IRCube : TCCON comparison
IRCube
HR126
difference on TCCON grid
Laser change
Mean diff: -0.0120
Mean diff: -0.0049
xAIR
xAIR difference
YEAR
YEAR

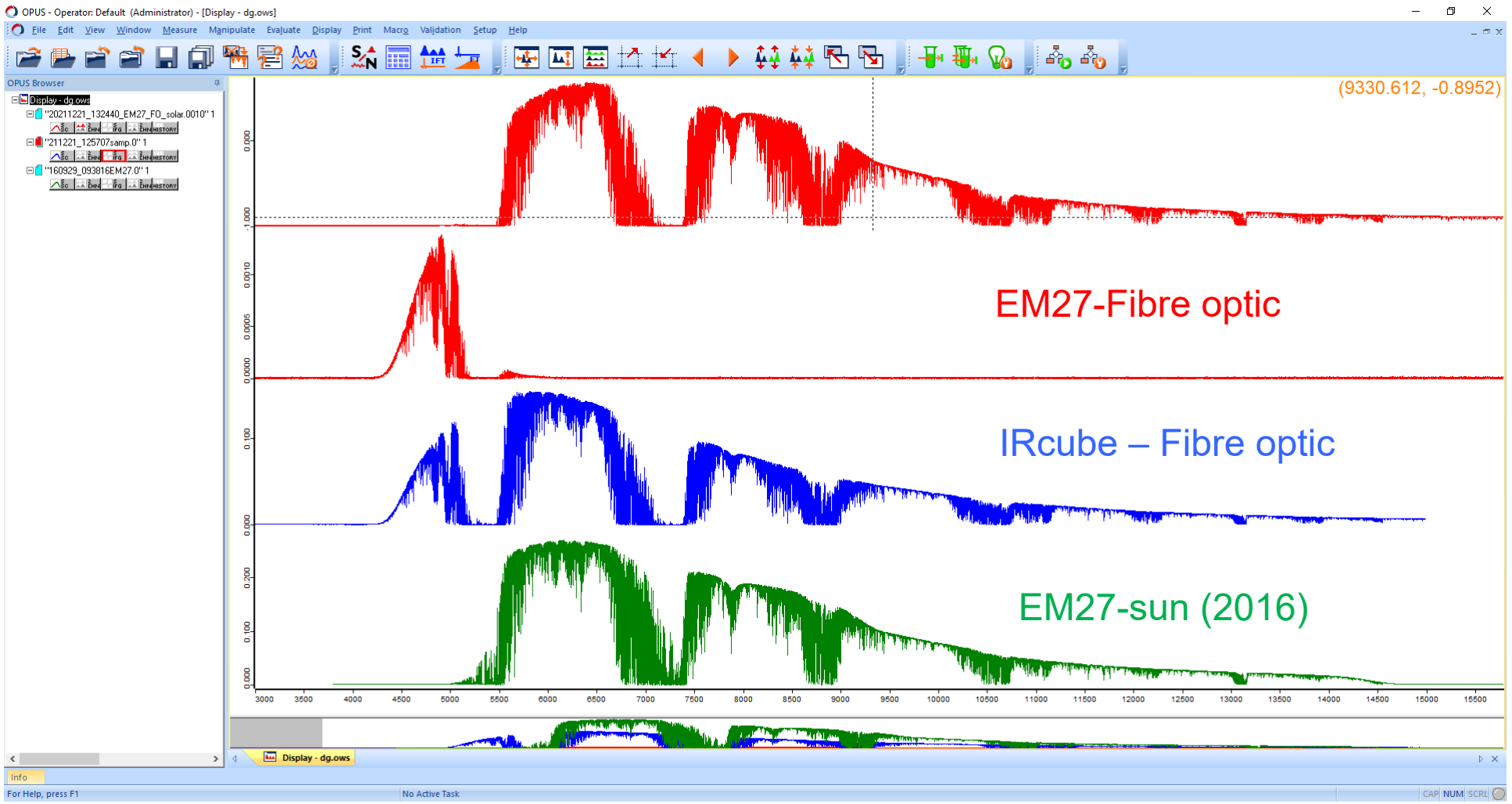
# xH2O


xH2O IRCube : TCCON comparison
IRCube
HR126
difference on TCCON grid
Mean diff: (ppm): -110.79
Mean diff: (ppm): -69.92
Laser change
xH2O [ppm]
8000
6000
4000
2000
0
2021.0
2021.2
2021.4
2021.6
2021.8
2022.0
2022.2
YEAR
xH2O difference (ppm)
200
100
0
-100
-200
-300

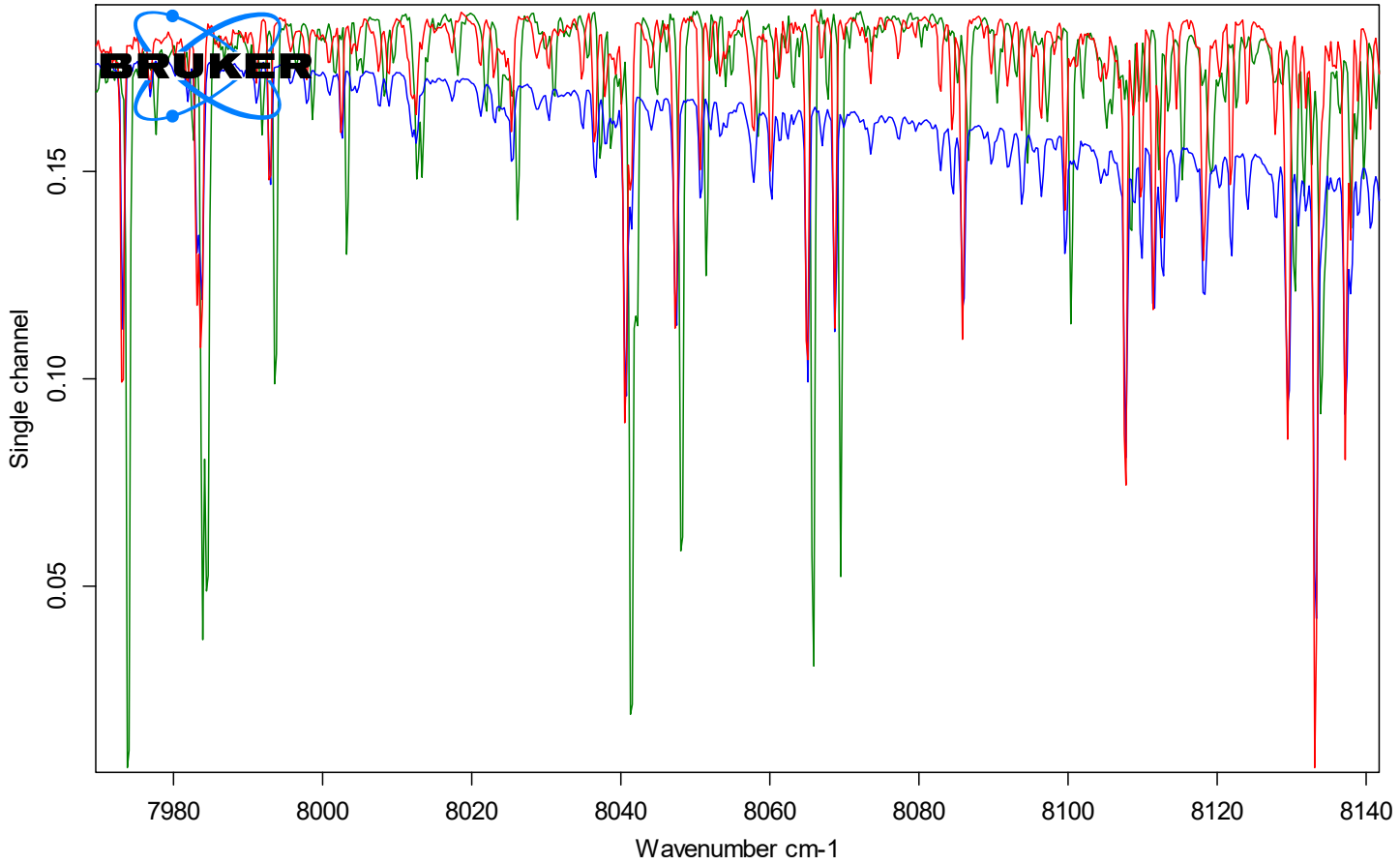
# Analysis, next steps

- Understand and investigate the change in ILS in 2022
- The modulation is 1.001, changed from 0.98 in November 2021.
- Reanalyse with GGG2020, Proffit, and SFIT4
- Investigate the use of a different end connector on the fibre optics: currently using a standard SMA connector but other types are much better in terms of consistent positioning of the fibre end.
- Also look again at the orientation of the fibre in terms of rotation.
- Get the TCCON O/P updated beyond August 2021.

# EM27 + fibre-coupled telescope-tracker



# No major fringing effects from FO




EM27-Fibre optic

IRcube – Fibre optic

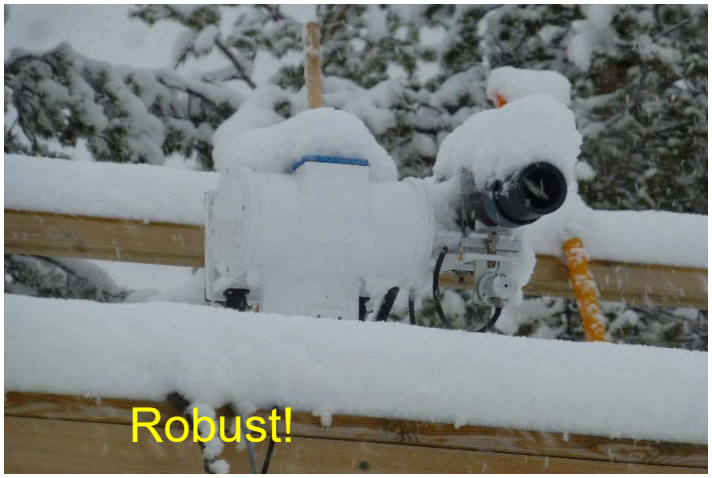
EM27-sun (2016)

| | | | |
|---|---|---|---|
| O:\Data\FRM4GHG\20211221_132440_EM27_FO_solar.0010 | Sun via Ekotracker and FO | | 2021-12-21 |
| O:\Data\FRM4GHG\211221_125707samp.0 | SolarCube | SolarCube | 2021-12-21 |
| O:\Data\FRM4GHG\160929_093816EM27.0 | EM27SUN setup | | 2016-09-29 |

**Page 1/1**

# EM27 – what next?

- Rebuild and fully align input optics
  - Simple lens collimates divergent beam from FO
  - Not optimised, SNR < EM27-sun or IRcube
- Dual telescopes on single tracker – new mount
- Second tracker is also available
- Parallel measurements
  IRcube, EM27, TCCON




# *Thank you for your attention*

# FRM4GHG-2

# KIT progress status during Oct 2021 – Mar 2022

**WP1, T3: improve alignment tools for low res spectrometers**

New LINEFIT version including new H2O line list has already been released, achieved improvements using new line list and additional micro window for investigating ILS have been published in AMT (Alberti et al, 2022).

Status: WP contribution by KIT fulfilled, closed

**WP2, T1: Improvements and extensions to PROFFAST, line lists update**

New PROFFAST version (line mixing and SDV implemented) available as beta version (including the new line lists)

Testing and verification of new code in progress (determine final gas-specific AIDCFs and ADCFs)

Further steps: generalize PREPROCESS for handling single-sided ifgs

**WP3, T2: Travel standard demonstration**

Required extensions / improvements on travel standard unit have been implemented and tested (e.g. allow wide range of power supply voltage, Vaisala pressure sensor included, acceleration detector included, …)

TS now on first site visit (NIES, Japan), taking measurements.

# Spectroscopic improvements for PROFFAST Ver 2

Presenter: Frank Hase, KIT

*frank.hase@kit.edu

https://frm4ghg.aeronomie.be/

# Spectroscopic improvements PROFFAST Ver 2

- Code improvements in support of wrapper development (quiet run option, parallelization, error handling,…)
- LOS airmass integration refined (4 -> 5 coeffs)
- Revised interpretation of measured ILS parameters (nominal EM27/SUN has mod eff amplitude of 0.983??), see C. Alberti et al.: “Improved calibration procedures …“, AMTD, 2021
- Support old + new TCCON/GGG map files (support wet + dry mixing ratios)
- Refined and updated TIPS table (use HIT20 data, 5 -> 7 coeffs)
- Extend line shape model (1st order LM, SDV)
- New line lists

  solar: transmission spectrum table (thanks to G. C. Toon!) GGG14 -> GGG20

  gases:

  ver 1: wild mixture (HIT08 with some empirical ad-hoc corrections, HIT12), $O_2$: GGG14

  ver 2: HIT20 ($H_2O$, $CO_2$ [+ LM + SDV], $N_2O$, CO, $O_2$ [+ SDV??])

  **special item: $CH_4$ HITRAN: LM under construction ~ 1 a, DLR line list covers only TROPOMI window (and uses HTP + 2nd order LM)**

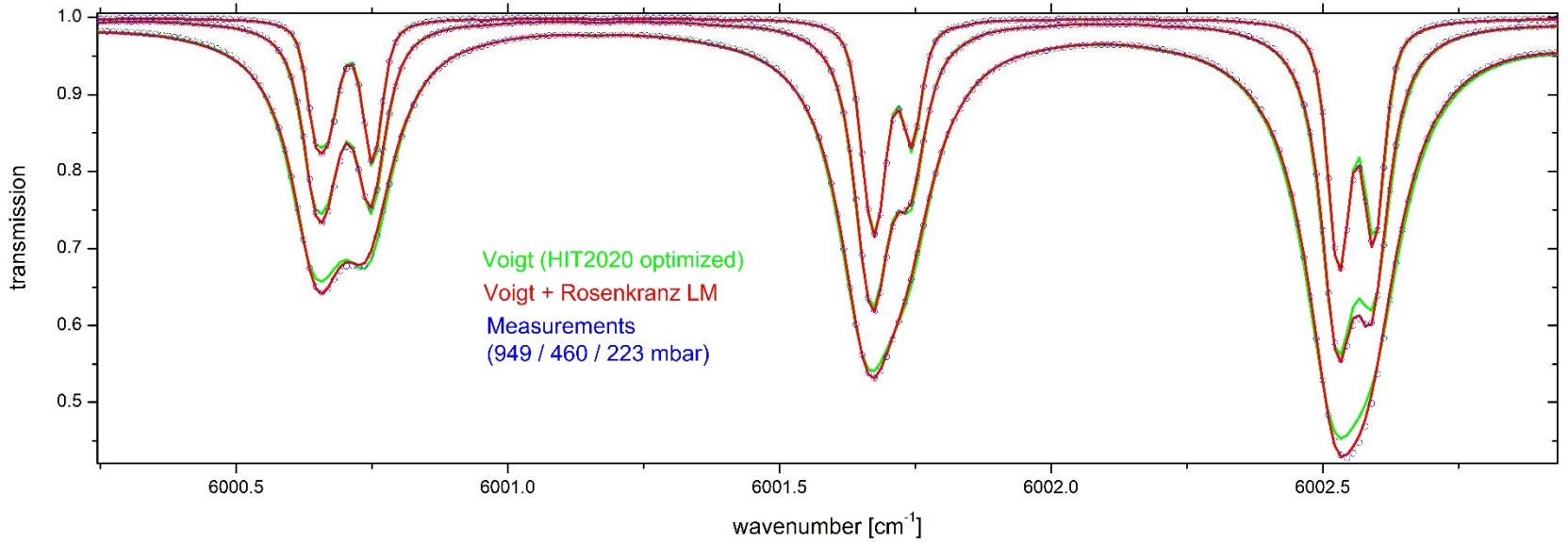
# Spectroscopic improvements PROFFAST Ver 2

- Perform room-temperature cell measurements: pure $CH_4$ and $CH_4$ in air (~ 1000, 500, 250, 125 mbar), develop a clever “poor-man‘s“ measurement strategy

| pressure | Fitted $CH_4$ column | ratio |
|---|---|---|
| 949.0 | 5.293e+23 | -- |
| 460.0 | 2.566e+23 | 0.4848 |
| 223.0 | 1.244e+23 | 0.4848 |
| 108.0 | 6.031e+22 | 0.4848 |

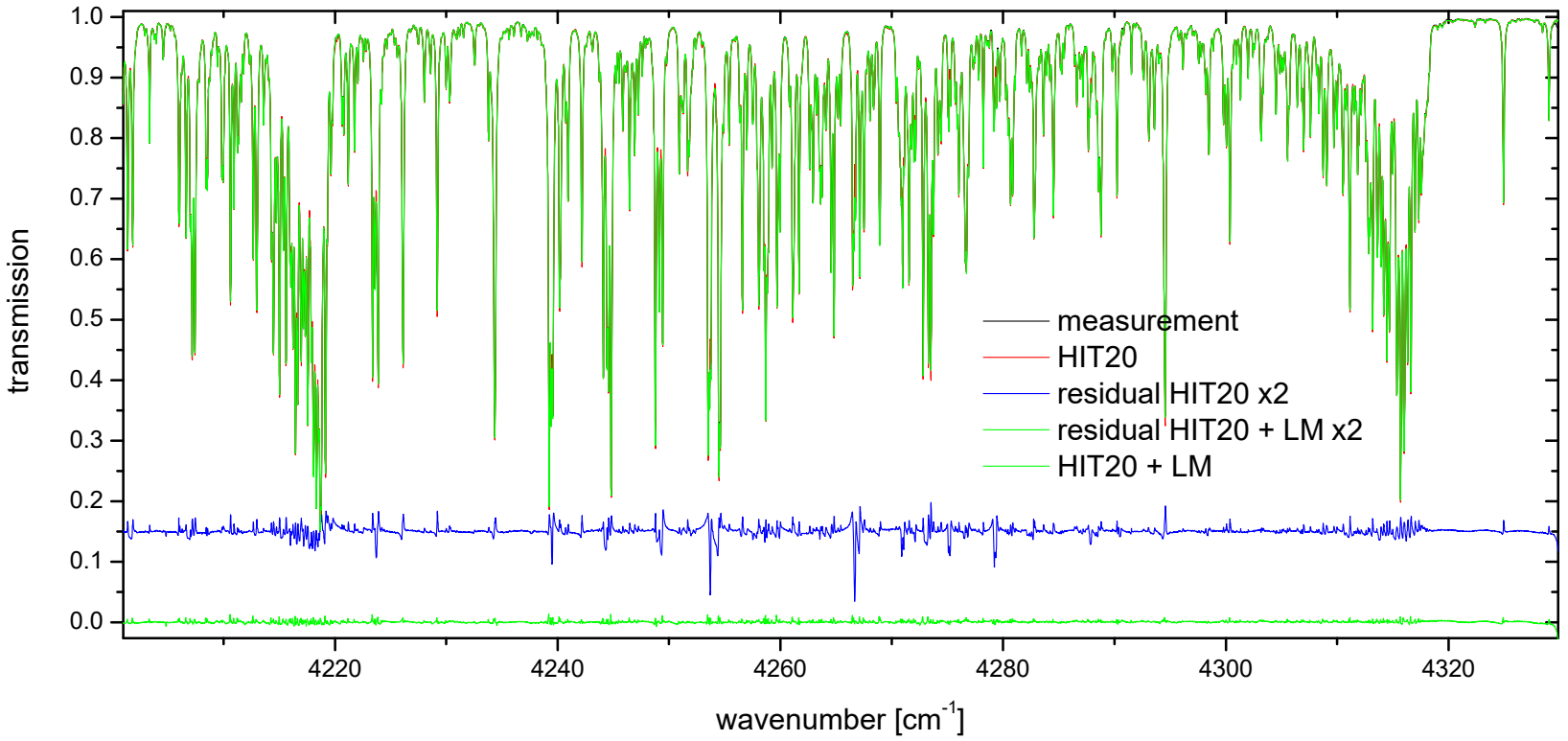
- coding of a multispectrum fitting tool

- Retrieval of optimized spectral parameters from available line lists and own measurements (*TROPOMI range:* DLR line positions + intensities consistent, only fit of p-dependent parameters, *TCCON range:* HIT20 line positions + intensities not satisfactory, ATM20 line list: significantly better than HIT20, not on DLR quality level, re-fit positions and intensities)


transmission
1.0
0.9
0.8
0.7
0.6
0.5
6000.5
6001.0
6001.5
6002.0
6002.5
wavenumber [cm-1]
Voigt (HIT2020 optimized)
Voigt + Rosenkranz LM
Measurements
(949 / 460 / 223 mbar)

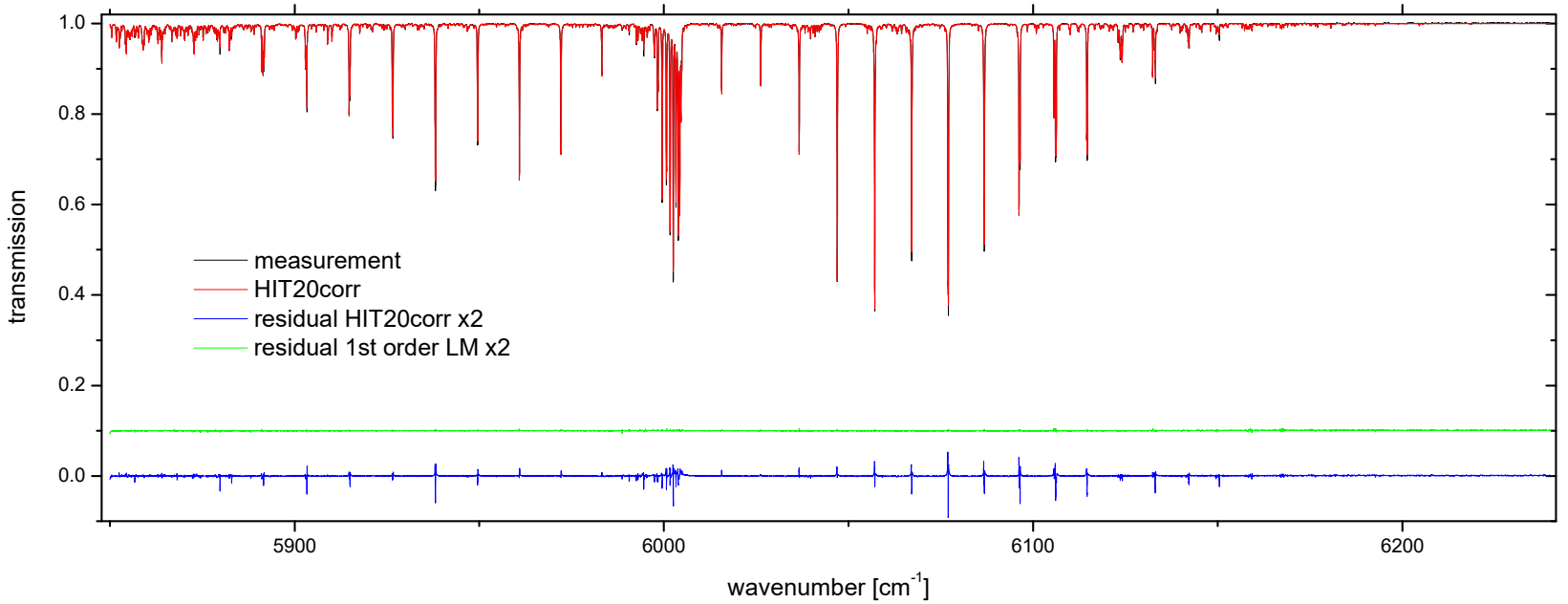
# Spectroscopic improvements PROFFAST Ver 2

Fit quality on 1000 mbar spectrum (note: multispectrum fit was performed).



# Spectroscopic improvements PROFFAST Ver 2

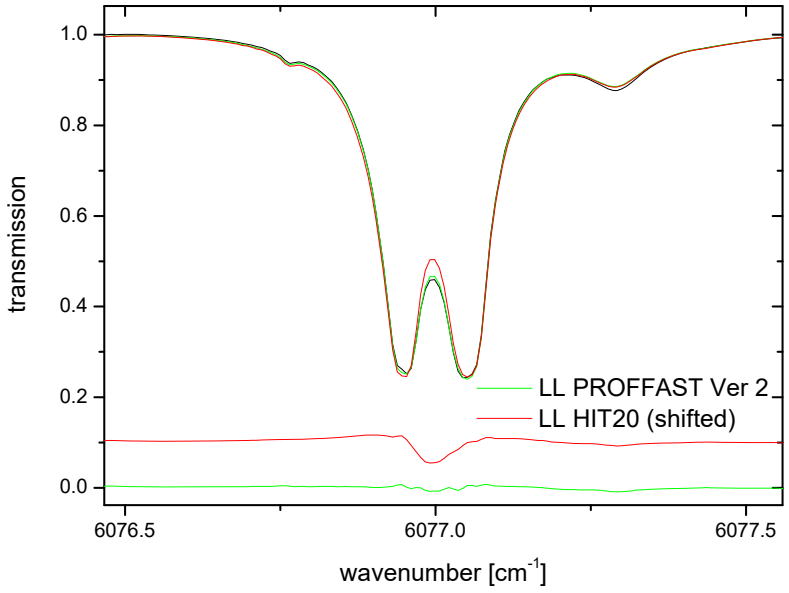
Fit quality on 1000 mbar spectrum (note: multispectrum fit was performed).

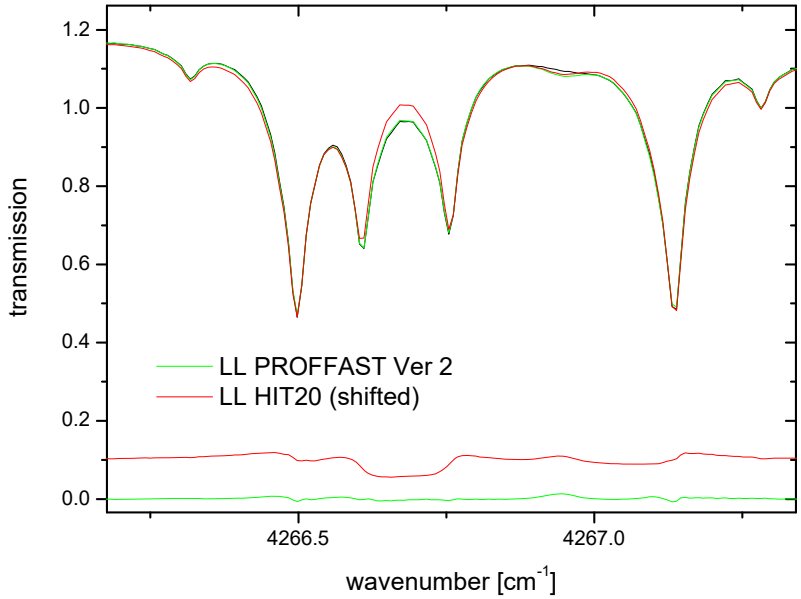


# Spectroscopic improvements PROFFAST Ver 2

Do the new $CH_4$ line parameters really work? - Tests on high-res solar spectra.

(Shown here: fits to average noon spectrum TCCON Ka 01-Aug-2019)



# Spectroscopic improvements PROFFAST Ver 2

**Preliminary** XGAS calibration results

| Ver 1 | Ver 2 (preliminary!!) |
|---|---|
| 0.8300, 0.000,0.0,"XH2O" | 1.0000, 0.000,0.0,"XH2O" |
| 0.9737,-0.007,0.0,"XAIR" | 0.9915,-0.007,-0.0045,"XAIR" |
| 0.9862, 0.005,0.0,"XCO2" | 0.9986, 0.000,0.0,"XCO2" |
| 0.9905,-0.014,0.0,"XCH4" | 0.9861, 0.002,0.0,"XCH4" |
| 0.9727,-0.017,0.0,"XCH4S5P" | 0.9913,-0.006,0.005,"XCH4S5P" |
| 0.9250, 0.103,0.0,"XCO" | 1.0000, 0.060,0.0,"XCO" |

- ✓ Ad-hoc post corrections are generally reduced.
- ✓ Fit residuals in TROPOMI window are reduced by ~40%.
- ✓ Spurious XAIR seasonal variability seems removed.

A reliable XHDO product might be in reach now for COCCON!

Fulfilled:

- ✓ New LINEFIT version (+ H2O line list for open path)
- ✓ Coding and testing of PROFFAST Ver 2
- ✓ Distribution of new code (and line lists and wrapper)
- ✓ Preliminary adjustment of gas calibration factors

Next steps:

- ➢ Final adjustment of calibration factors (can be supported by FRM4GHG partners…)
- ➢ Provision of a spectrometer to FMI
- ➢ Further incremental code + line list improvements
- ➢ Evaluation of user feedbacks, comparisons with GGG2020

Further steps:

- o Enable PREPROCESS to accept Vertex & IRcube spectra
- o …

*Thank you for your attention!*

# Progress Report Travel Standard, WP3 T2

Benedikt Herkommer*, Matthias Frey(NIES), Carlos Alberti, Jochen Groß, Frank Hase

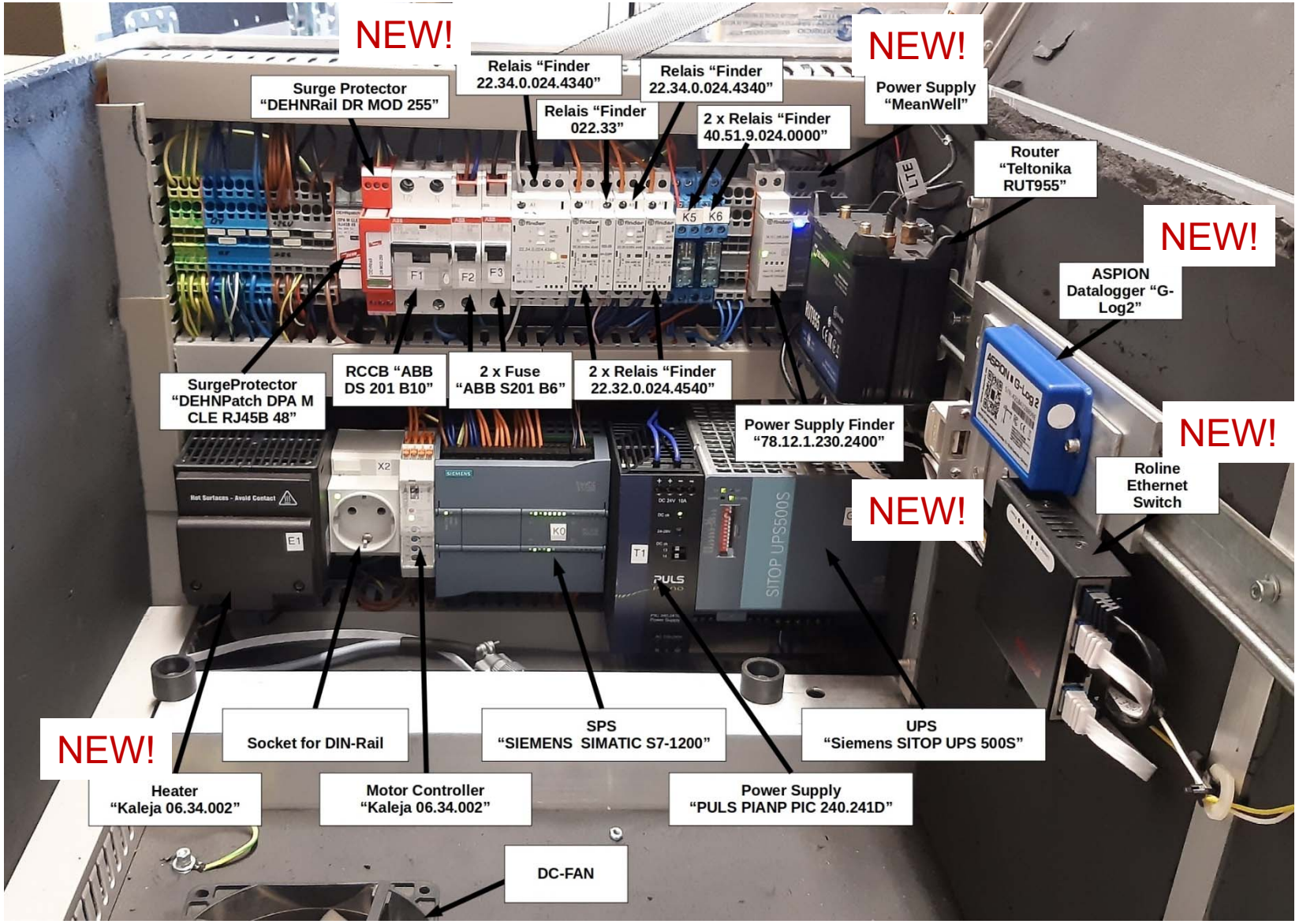
*benedikt.herkommer@kit.edu https://frm4ghg.aeronomie.be/

# Objectives

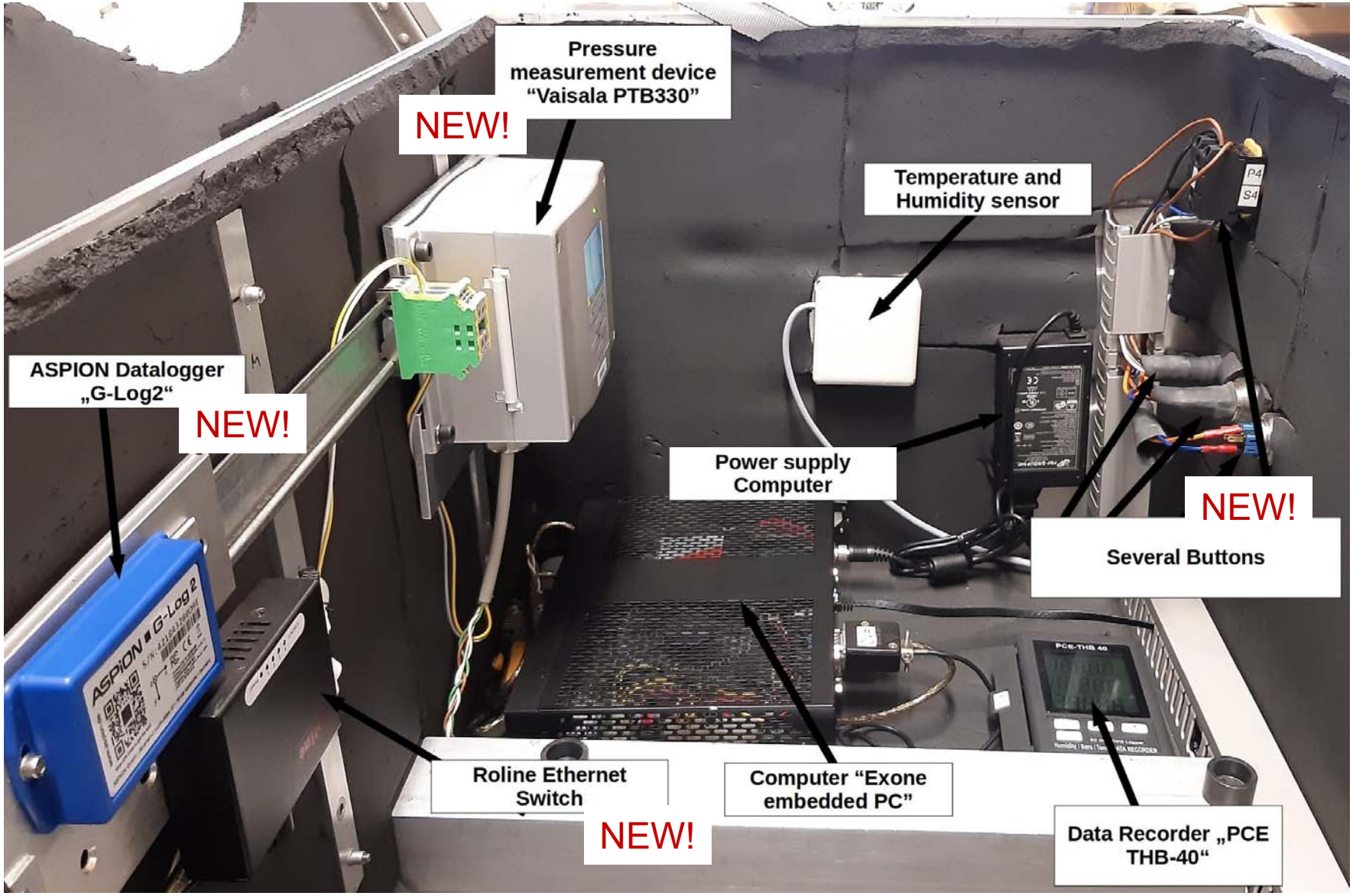
**Current Progress:**

- **Hardware work:**
  - Changed power supply: Works now with a wide range power supply
  - Installed additional Gigabit Ethernet switch: Enabling support for the new Camera used by Bruker
  - Internal USB-Power supply for external LTE-Router
  - Mounted Vaisala PTB330 sensor inside the box for reliable pressure measurements
  - Datalogger to monitor transport (temperature, vibrational shocks)
- **Logistical**: Shipment to Japan
  - Shipped at February 9th, arrived at March 22nd. Delay due to German custom.
- **Measurements**: First measurements performed + evaluated in Japan

# Hardware work



# Hardware work

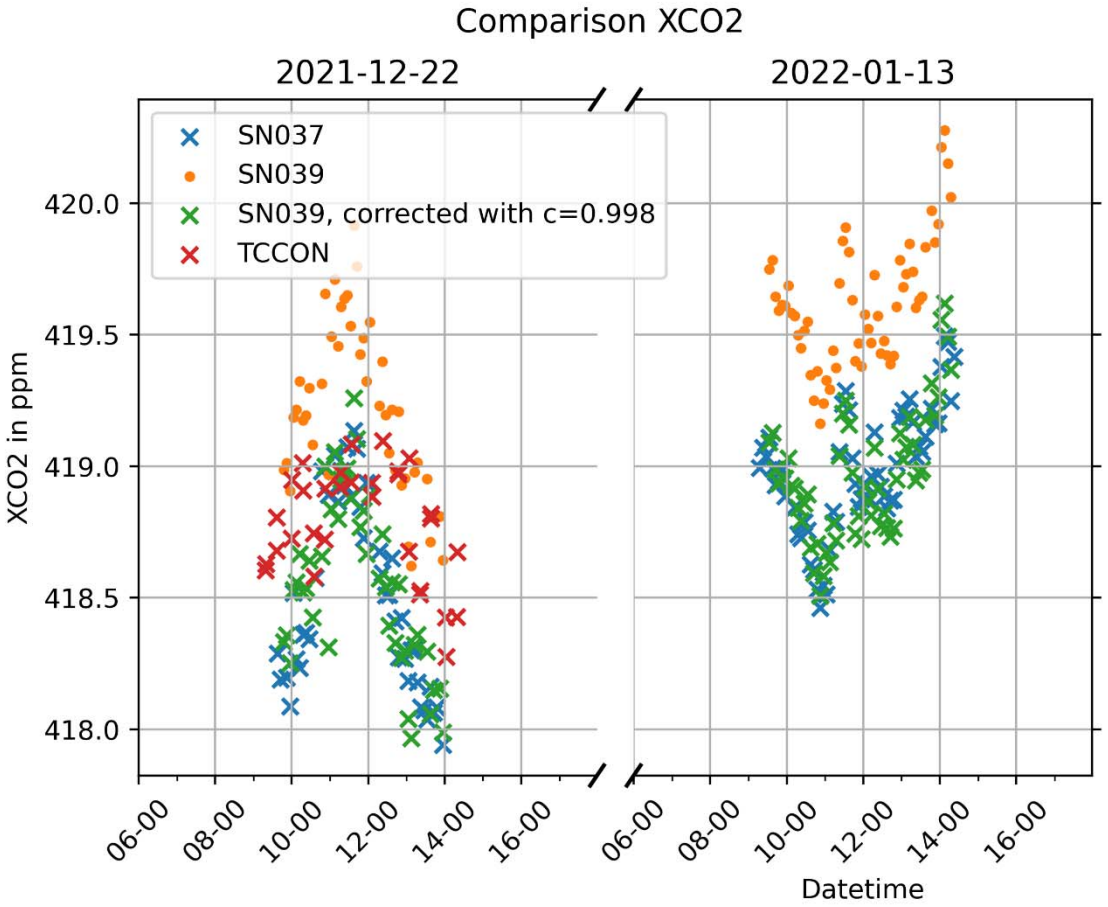


# Logistical: Shipment to Japan

Final assembly of the unit in Japan and first measurements where performed.

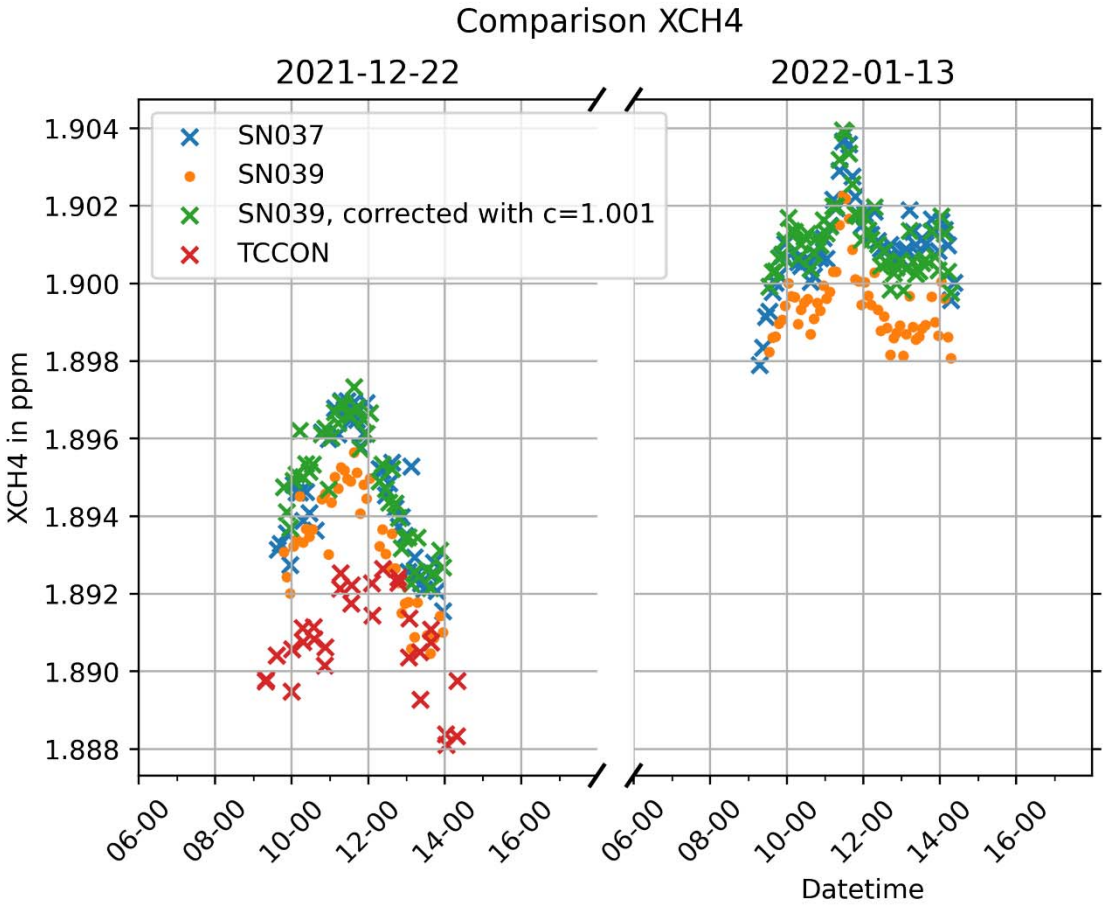
# Measurements: Side-by-Side in KA

XCO2 : SN039 (Travel standard) vs. SN037 (COCCON reference)



# Measurements: Side-by-Side in KA

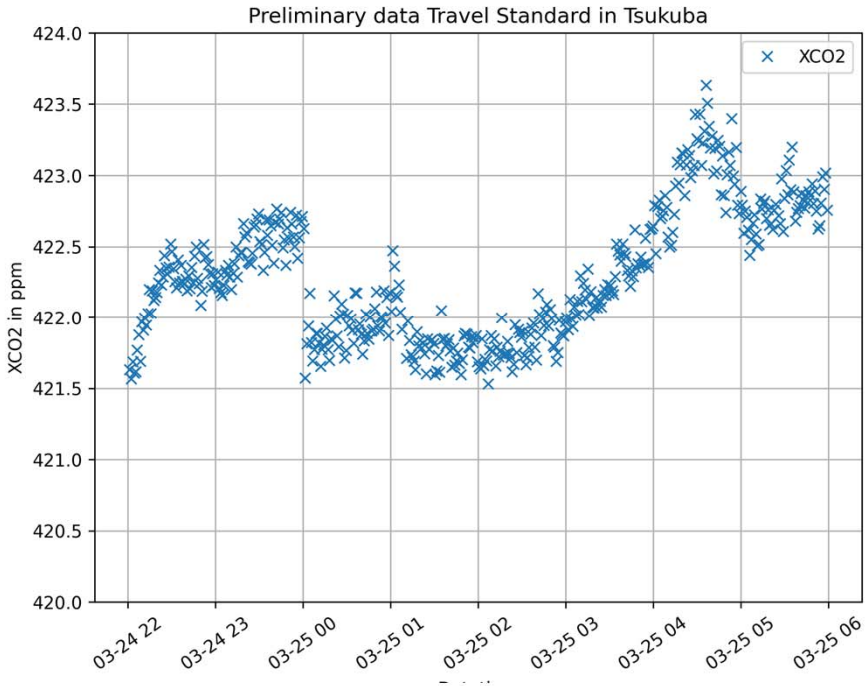
XCH4: SN039 (Travel standard) vs. SN037 (COCCON reference)

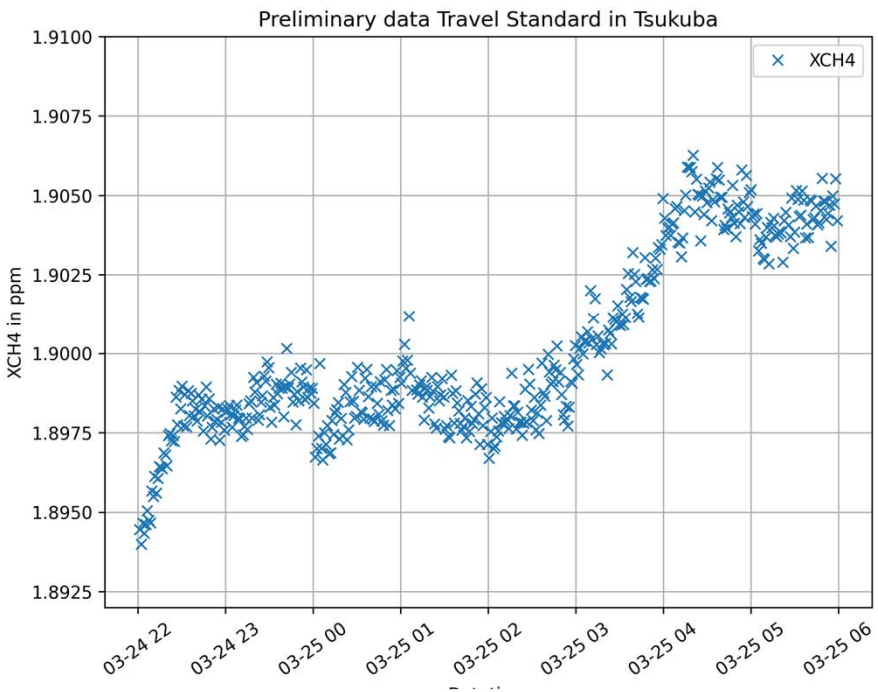


| Date | KXCO2 | KXCH4 |
|---|---|---|
| 2014-07-17 | 0.999764 | 0.999566 |
| 2015-04-14 | 0.999563 | 0.999660 |
| 2015-04-15 | 0.999676 | 0.999691 |
| 2021-12-22 and 2022-01-13 (Comparison of the author) | 0.998435 | 1.000886 |

# First measurements in Tsukuba

XCO2(left) and XCH4(right), without TCCON comparison




- High intraday variability probably due to influence of Tokyo in near neighborhood
- Data is of great interest for scientific work ans S5P validation → Upload to EVDC-Database

# *Thank you for your attention*

# Progress of LHR related activities

Damien Weidmann* and Neil Macleod.

Science and Technology Facilities Council

RAL Space

*damien.weidmann@stfc.ac.uk

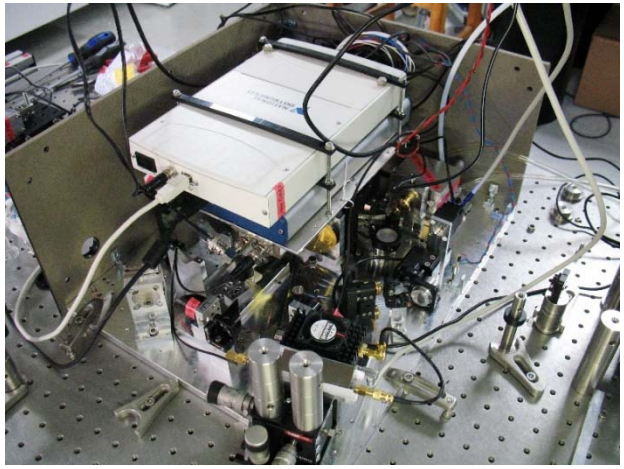
https://www.ralspace.stfc.ac.uk/Pages/Spectroscopy.aspx

# Outline

- Background reminder
- Dedicated heliostat development
- Installation along Harwell TCCON
- Next steps

# Laser Heterodyne spectro-Radiometer

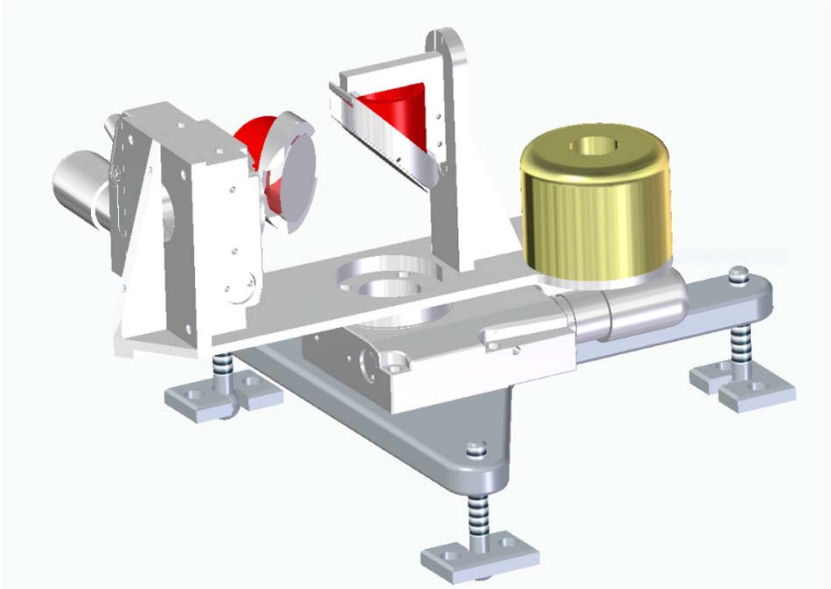
- LHR rationale
  - Research instruments in development
  - Complementarity TIR/NIR bands
  - Addressing issues identified during FRM4GHG 1
- LHR features
  - Operates with Quantum Cascade Lasers
  - Coherent detection (optical photomixing)
  - Operates in the thermal infrared (10.5 and 8.1 μm)
  - High spectral resolution (0.01 to 0.001 $cm^{-1}$)
  - Full remote operation
  - Miniaturizable

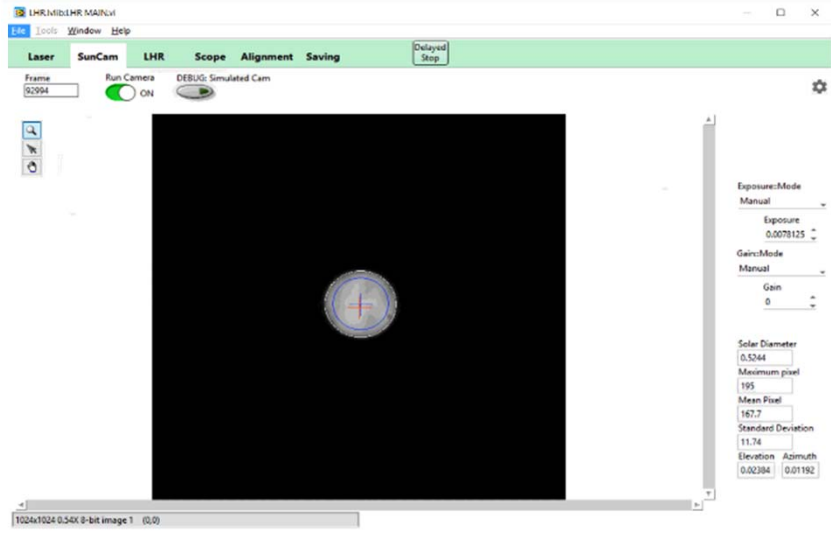



Weidmann, *Atmospheric trace gas measurements using laser heterodyne spectroscopy*, Chapter 4 in Advances in spectroscopic monitoring of the atmosphere, Elsevier, 10.1016/B978-0-12-815014-6.00005-1

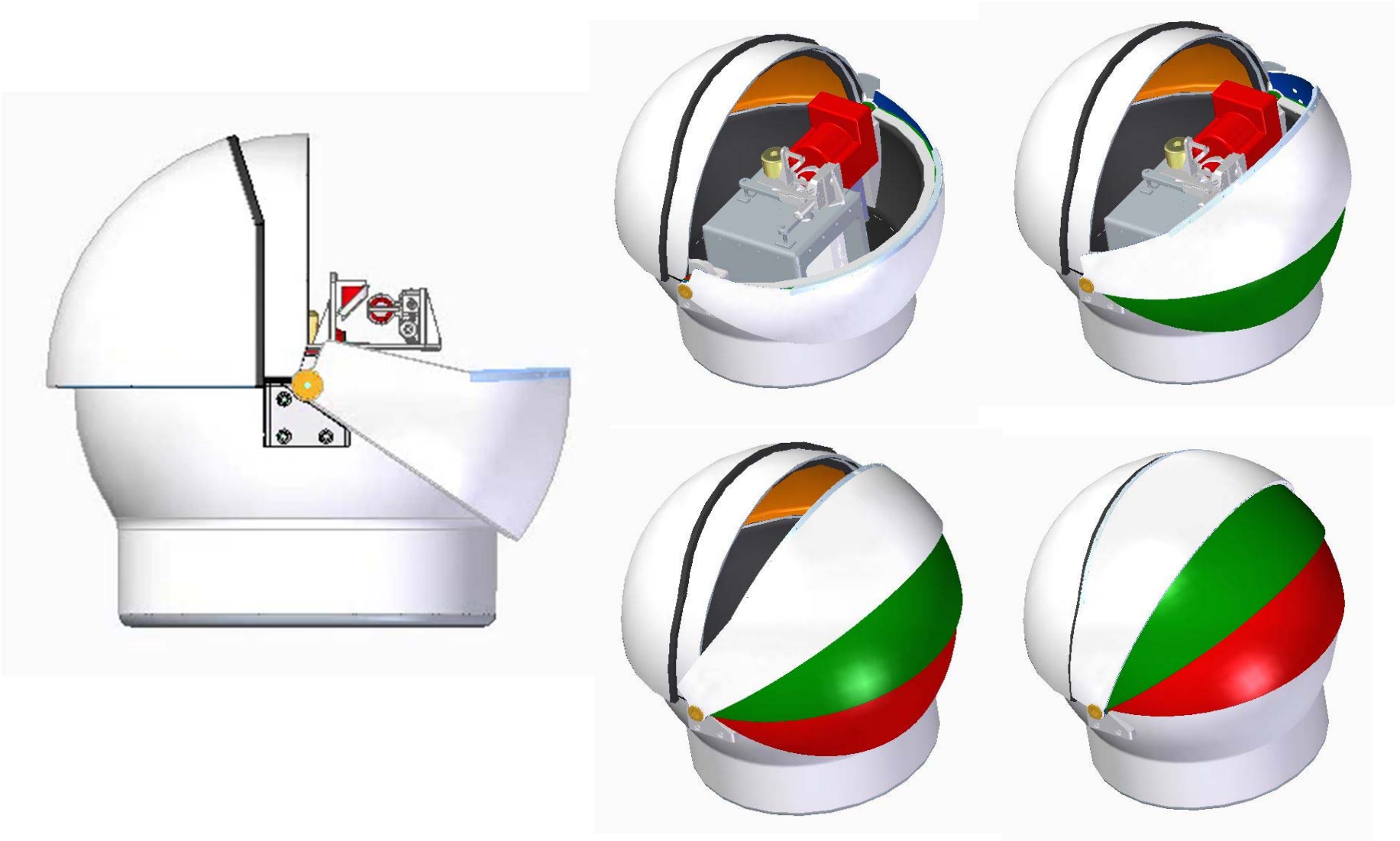
# Dedicated Cam-Tracker Development

- Miniaturized Alt-Az
  - 2.5 cm mirror aperture
- Coupled to Cam-tracking software
  - Active and passive mode
  - Ensure co-centricity
  - 100 ms update rate
- External dome shell
  - 220 degree azimuth access view
  - 90 degree elevation view
  - Outdoor operation
  - Clam-shell design retained





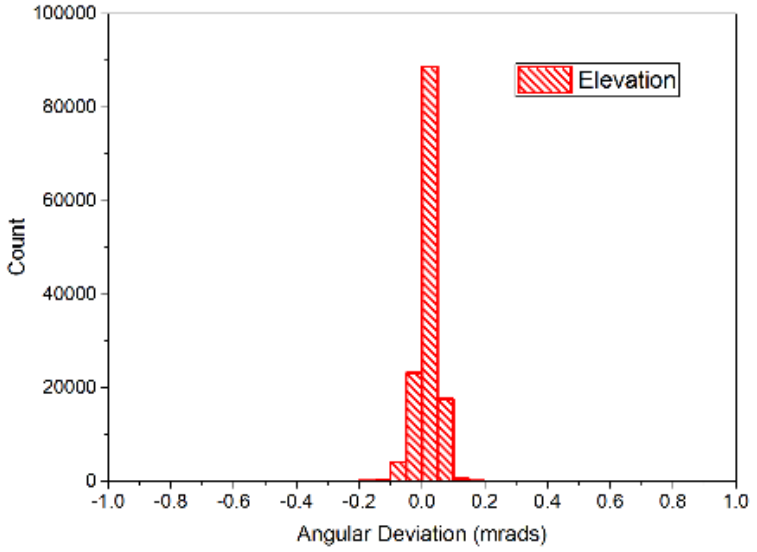
# Clam Shell Design

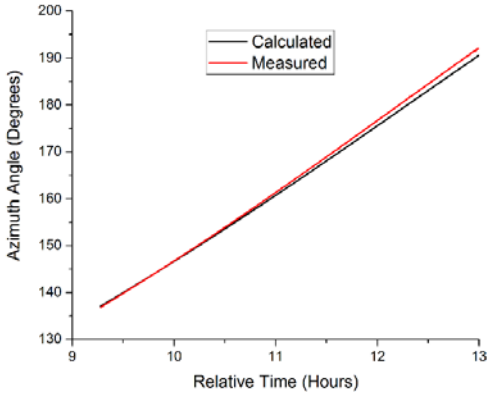


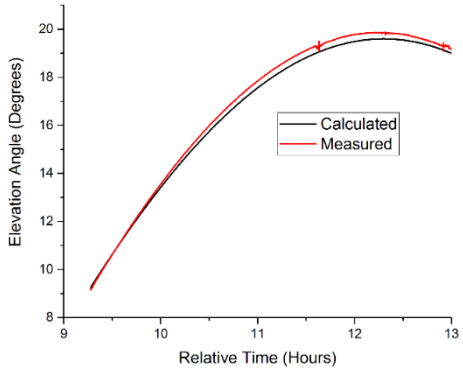
# Assembled Solar Tracker

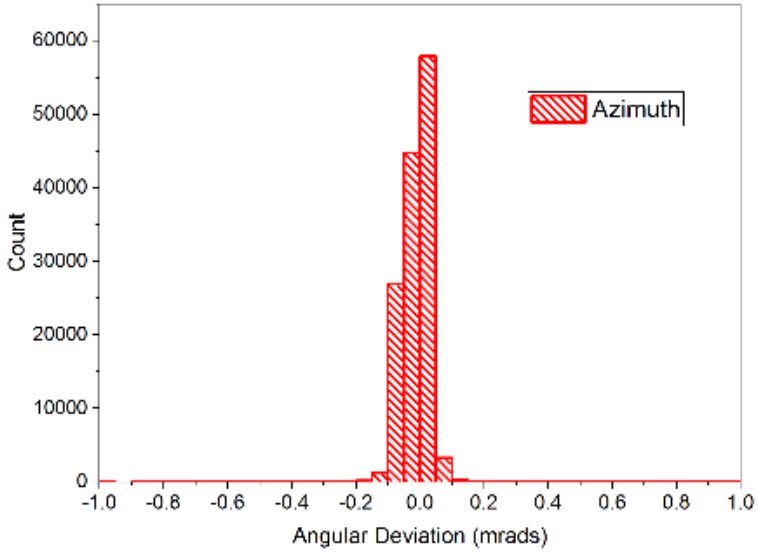
# Tracking Performances

- 3σ pointing precision
  - <0.15 mrad
- Robust to cloud interferences
- System nearly ready to deploy
  - Survival heating still to be implemented



# LHR Installation in TCCON Dome

# Plan for LHR/TCCON Measurements

- Simultaneous co-located measurements
- Enables immediate instrument feedback

- LHR alterations
  - New filters
  - Modulator replacement
  - Re-alignment and optimization

# Next steps

Hardware

- Camera upgrade for sun tracker
- LHR re-commissioning
- Simultaneous LHR/TCCON campaign

Software

- Improved L1 processor
- Repackaged OEM L2 processor
- Data / bias re-analysis

# *Thank you for your attention*

# RUG progress in WP 1 – 3 during Oct 2021 – Mar 2022

Huilin Chen, Steven van Heuven, Alessandro Zanchetta, University of Groningen
Rigel Kivi, Pauli Heikkinen, Finnish Meteorological Institute

Huilin.Chen@rug.nl https://frm4ghg.aeronomie.be/

# RUG Leading/Participating Tasks

- **WP1 T4 (RUG, FMI) Develop AirCore for retrieving OCS and $N_2O$ in addition to $CO_2/CH_4/CO$**

- **WP2 T5 (FMI, RUG): Improving AirCore retrievals and historical AirCore dataset**

# RUG Leading/Participating Task I

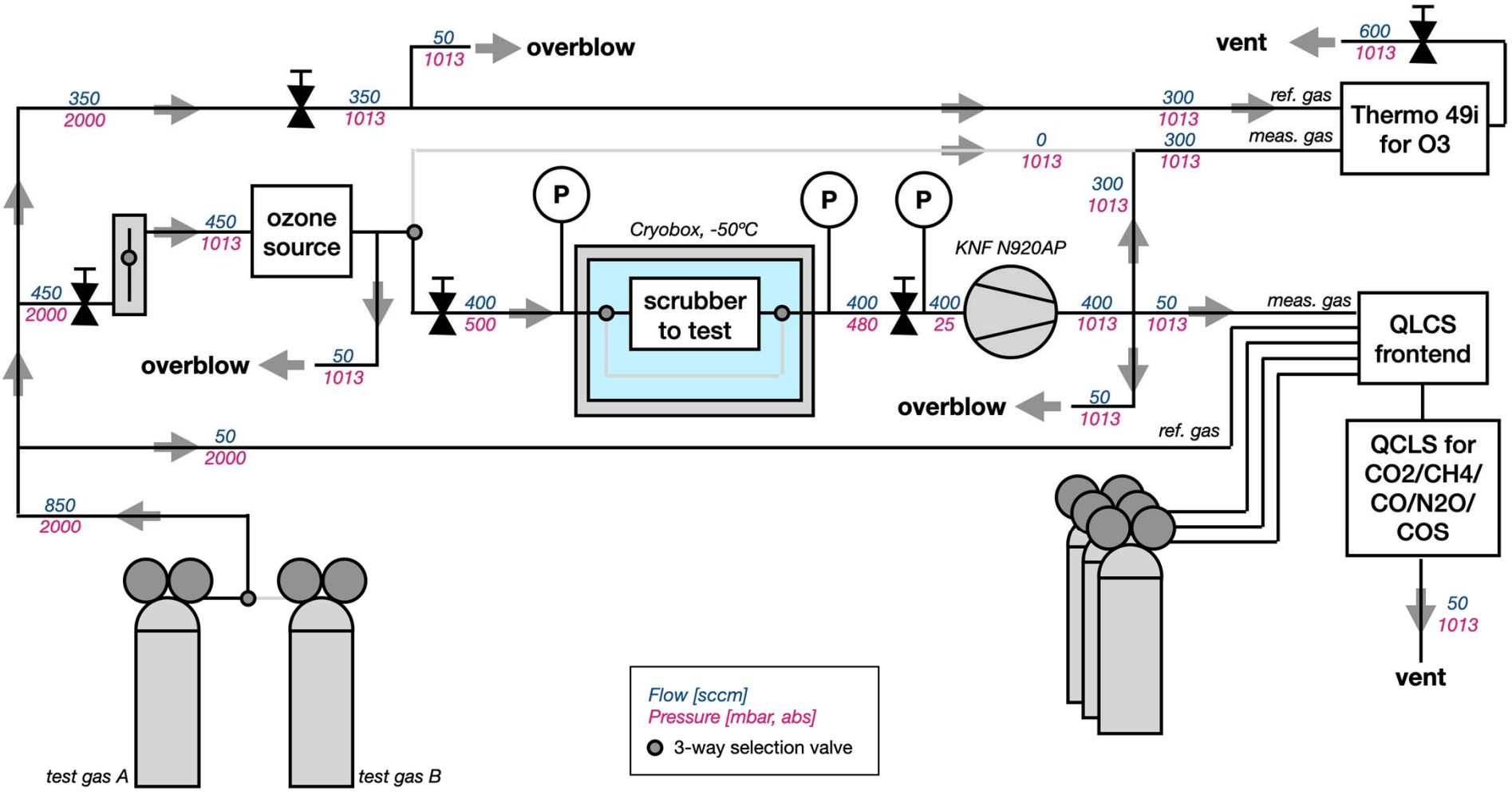
## WP1 T4 (RUG, FMI) Develop AirCore for retrieving OCS and N2O in addition to CO2/CH4/CO

- Test the potential impact of the RUG newly developed ozone scrubber on CO2/CH4/CO measurements **(Cotton, good CH4/CO, slight depleting CO2 )**
- Design the calibration strategy for OCS and N2O, especially for their low concentrations **(Initial design using Zero air, to be assessed)**
- Compare AirCore OCS and N2O measurements with and without an ozone scrubber **(Planned August 2022, to be confirmed)**

D1.4.1 Report on OCS profile measurements by AirCore (RUG&FMI, M48)
Specifications and performance of AirCore for OCS profile measurements: report

D1.4.2 Report on N2O profile measurements by AirCore (RUG&FMI, M48)
Specifications and performance of AirCore for N2O profile measurements: report

# WP1 T4 (RUG, FMI) AirCore for OCS and N2O: AirCore Development



# WP1 T4 (RUG, FMI) AirCore for OCS and $N_2O$: AirCore Development

- **QCLS now suited for simultaneous detection of $CO_2$, $CH_4$, $N_2O$, CO, COS and $O_3$**

- **Cotton pads chosen as the candidate $O_3$ scrubber**
  - Heated steel (batteries and resistance wire)
    - Cumbersome, not very efficient, modifies CO, COS
  - $MnO_2$-coated mesh
    - Very compact, very efficient, modifies CO, COS
  - Pelletized MnO2
    - Compact, efficient, modifies CO, COS (direction variable after cold soak?!)
  - Cotton pads (hint from commercial aviation literature)
    - Light, low capacity (but for AirCore not much air is sampled anyway)
    - No effect on $N_2O$, COS, CO, $CH_4$ (under test conditions)
    - Slight $CO_2$-depleting effect (possibly due to NaOH treatment during cotton production – must test washing or pre-soaking prior to flight)
- **Initial deployment on cryogenic sampler shows severe contamination for COS (fair for $N_2O$, can't assess for CO, because cryosampler not suited)**
  - Contaminated surfaces of catalyst container?
  - Insufficient evacuation of catalyst container prior to deployment?
  - Effusion from cotton lumen (organic cells!) during 48h stand time after evacuation?
- **Promising candidate, but more testing needed!**
- **We'll be testing deployment with a stratospheric mixture as fill gas (low $N_2O$, $CH_4$, COS, normal $CO_2$. CO spiked(?)).**

# RUG Leading/Participating Task II

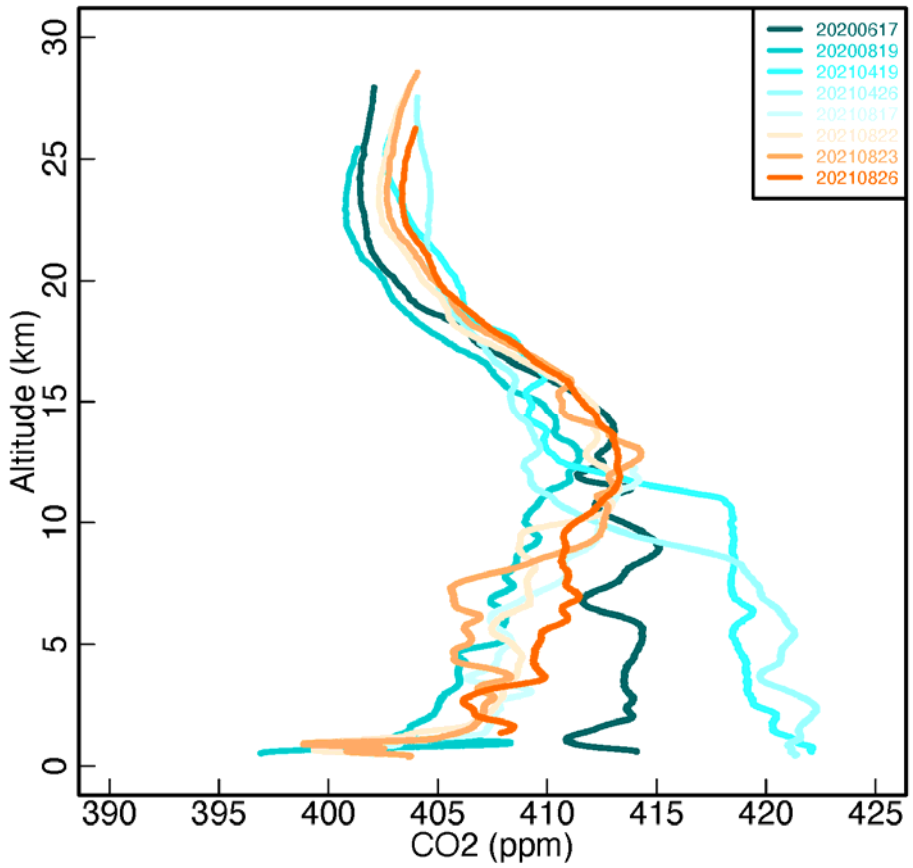
## WP2 T5 (FMI, RUG): Improving AirCore retrievals and historical AirCore dataset

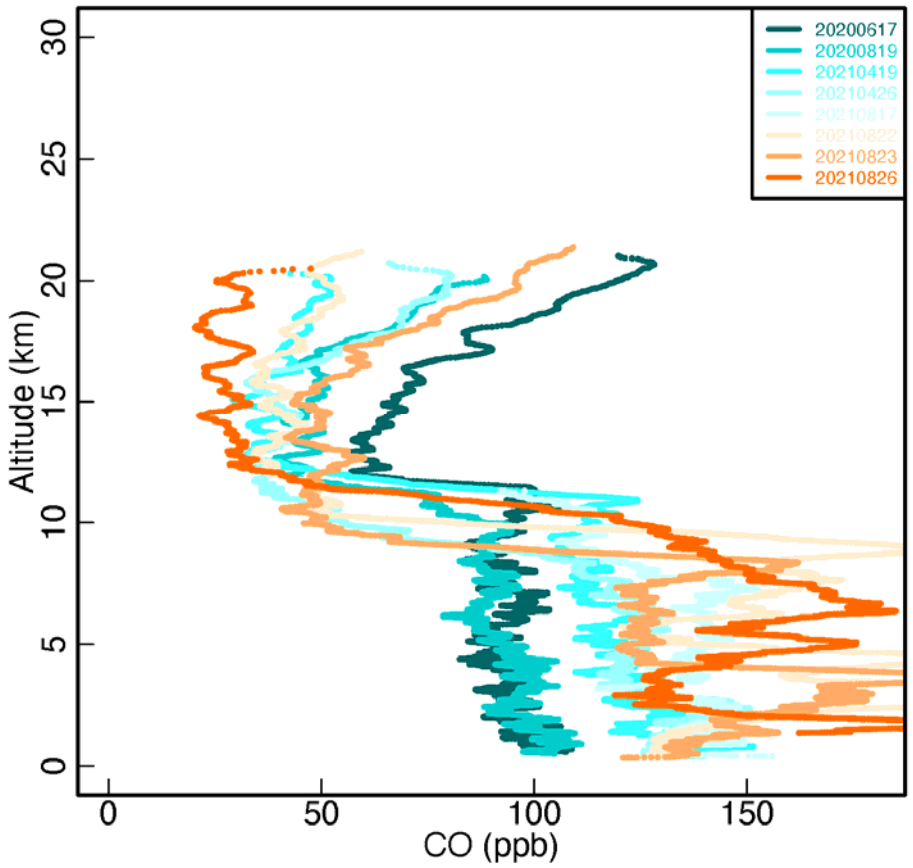
- Perform additional AirCore launches during the 4 years of the project to have enough statistical coverage (**2021 6 profiles processed, 2022 to be done**)
- Improve retrieval of CO and CH4 profiles in the stratosphere from AirCore measurements based on dual launches and LISA launches at Sodankyla **(Planned August 2022, to be confirmed)**
- Reprocess all 2017-2019 AirCore data at Sodankyla **(Not started, wait until the dual launches are done)**

D2.5.1 TN: AirCore retrieval procedure updates (RUG, M36)
Improved retrieval procedure for CO and CH4 profiles in the stratosphere

D2.5.2 Aircore Dataset (RUG&FMI, M48)
AirCore dataset version 2.0 = Homogeneous series of CO2, CO and CH4 profiles from AirCore launches at Sodankyla in the 2017-2024 period. The dataset will be included in WP4 - D4.2.3

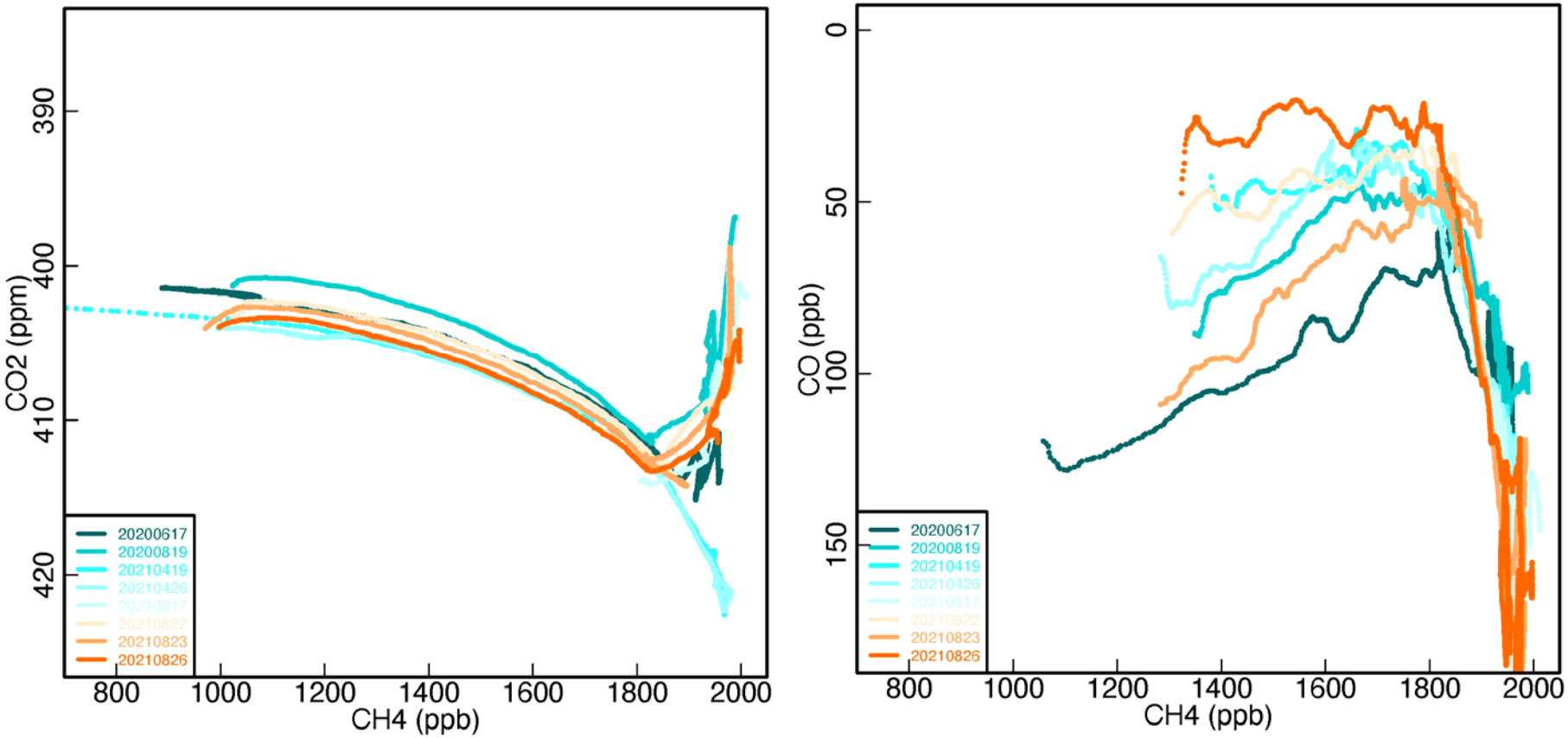
# WP2 T5 (FMI, RUG): Improving AirCore retrievals and historical AirCore dataset



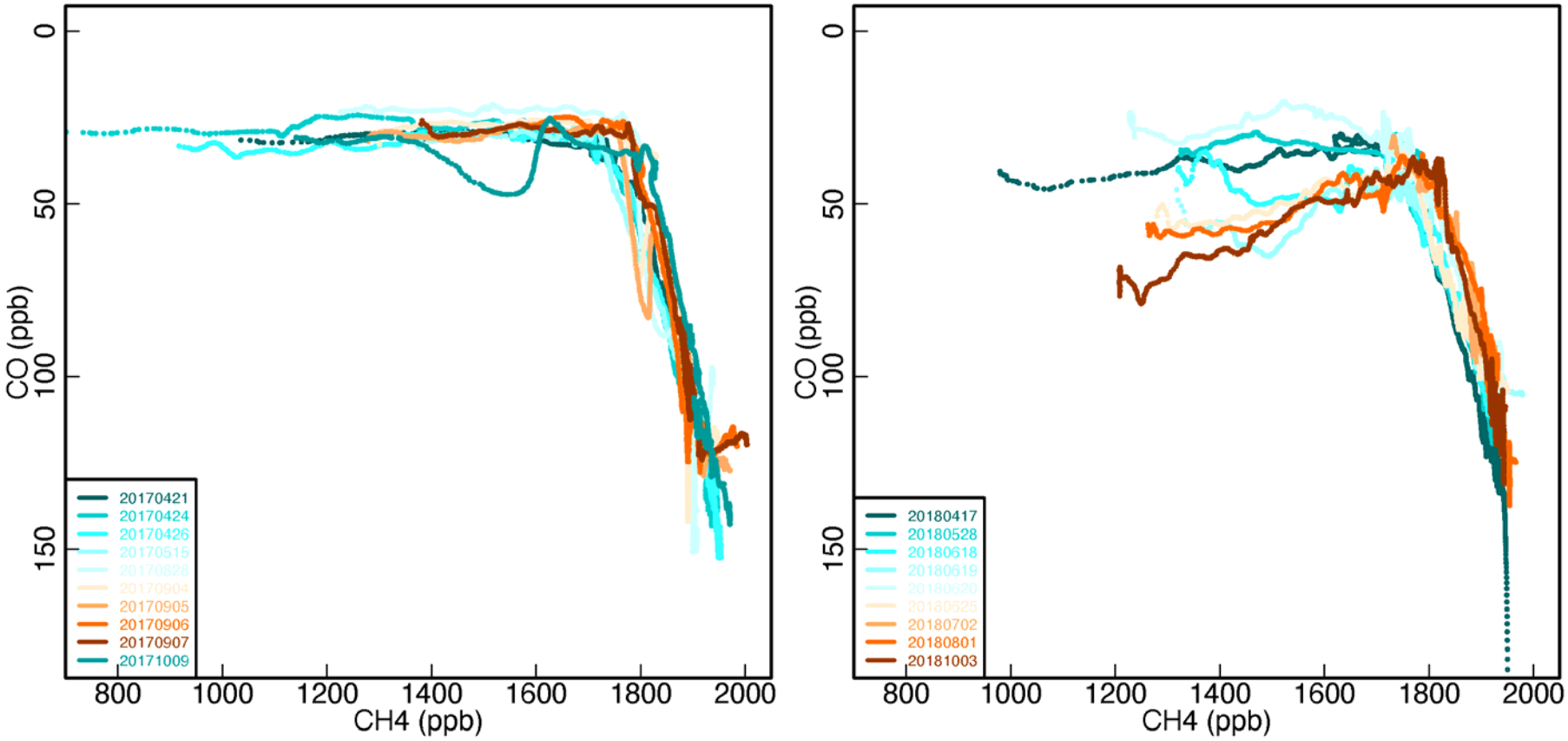

- Six profiles in 2021 (2 April, 4 August)
- Consistency good for $CO_2$, but variable for CO (**nothing new**)

# WP2 T5 (FMI, RUG): Improving AirCore retrievals and historical AirCore dataset

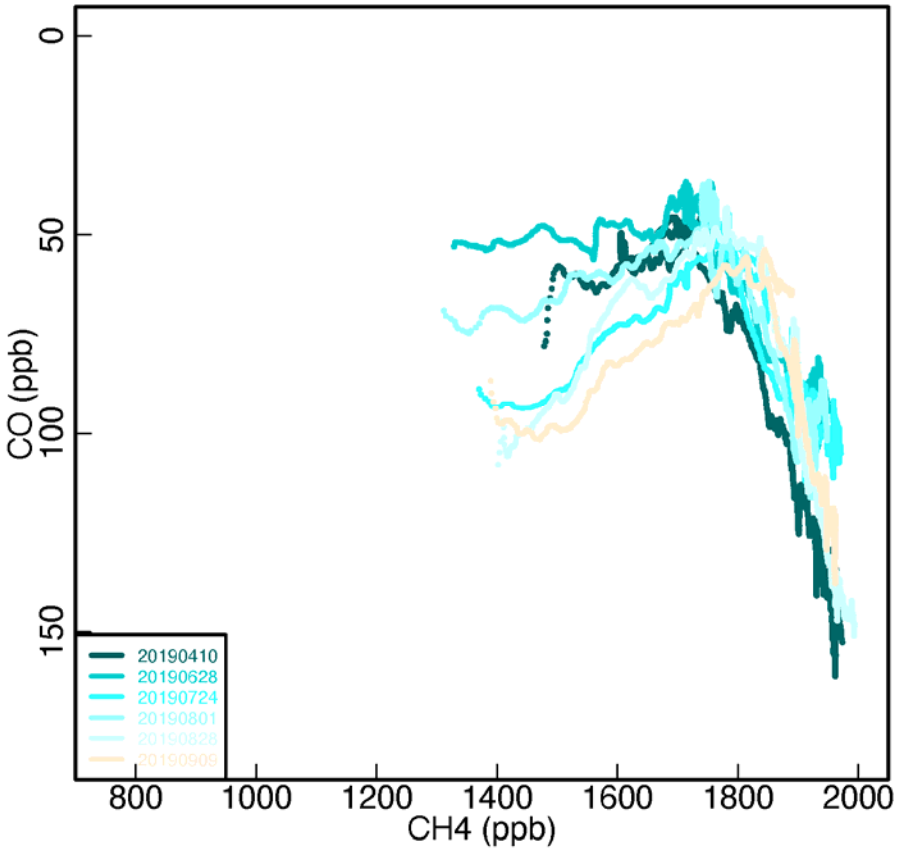


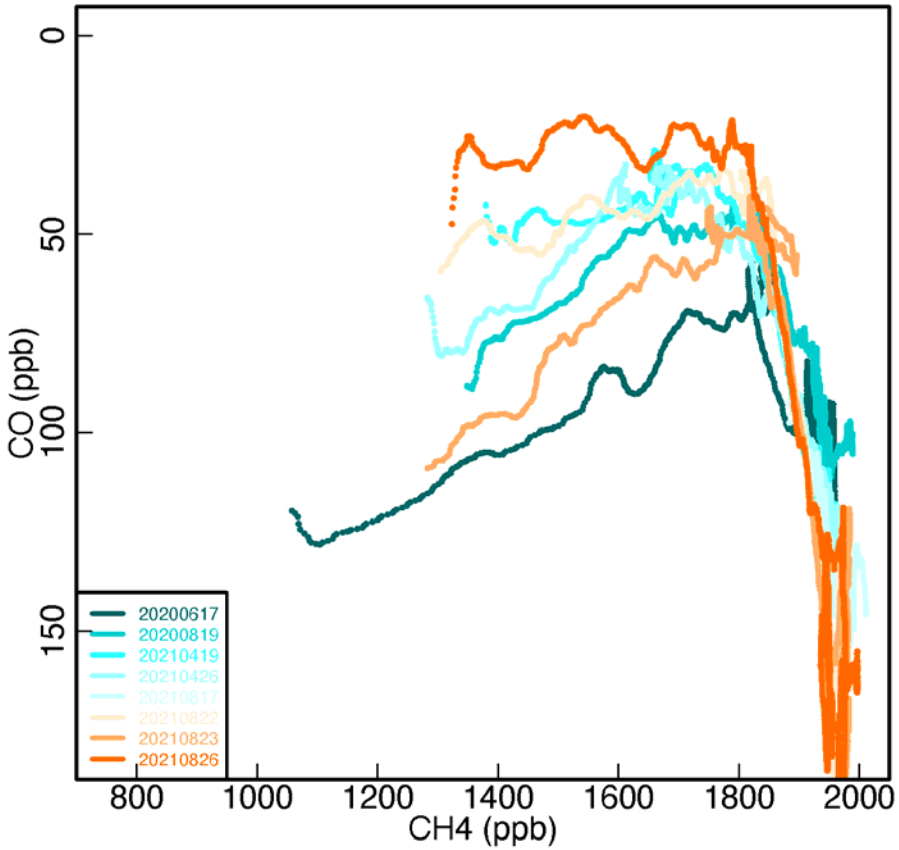

- Consistency good for $CO_2$, but not for CO (**nothing new**)
- Hypothesis: surface coating issue?

# WP2 T5 (FMI, RUG): Improving AirCore retrievals and historical AirCore dataset



# WP2 T5 (FMI, RUG): Improving AirCore retrievals and historical AirCore dataset




- Hypothesis: surface coating issue? Yes, quite likely
  - Dual AirCore flights
  - Recoating the surface

# *Thank you for your attention*