Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations (FRM4GHG) campaign at the Sodankylä TCCON site

Rigel Kivi, Pauli Heikkinen (1), Justus Notholt, Christof Petri (2), Martine De Mazière, Mahesh Kumar Sha, Christian Hermans (3), Thomas Blumenstock, Frank Hase, Qiansi Tu (4), Huilin Chen (5, 6), Joram Hooghiem (5), David Griffith, Nicholas Jones (7), Damien Weidmann, Alex Hoffmann, Marko Huebner (8)

1) Finnish Meteorological Institute, Sodankylä, Finland, 2) University of Bremen, Bremen, Germany, 3) Royal Belgian Institute for Space Aeronomy, Brussels, Belgium, 4) Karlsruhe Institute of Technology, Karlsruhe, Germany, 5) Center for Isotope Research, University of Groningen, Groningen, Netherlands, 6)Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado, USA, 7) University of Wollongong, Wollongong, Australia, 8) Rutherford Appleton Laboratory, United Kingdom

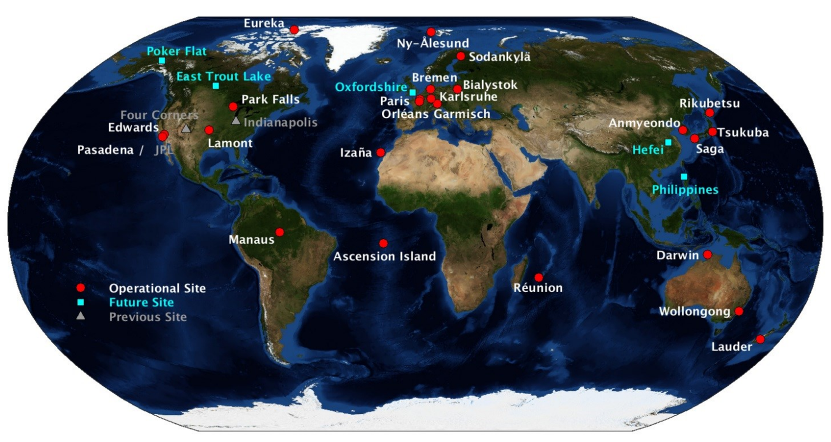
1. FRM4GHG Project

- Recently several new portable infrared spectrometers have become available for ground based solar infrared absorption measurements of total column greenhouse gas amounts.
- However, the performances of these instruments have not been fully characterized, and the ongoing ESA funded campaign "Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations (FRM4GHG)" at the Sodankylä TCCON site aims at characterizing several of the portable spectrometers and their measurements.
- The measurements within the campaign started in March 2017. The campaign is performed for nearly a whole year to cover different atmospheric conditions.
- The remote sensing measurements are accompanied by AirCore balloon (*Karion et al., 2010*) launches from the Sodankylä site. The AirCore in situ reference profiles will be used to verify the calibration of the remote sensing instruments involved.
- The campaign focuses on CO and CH_4 measurements in support of the ESA Sentinel-5P validation. In addition also CO_2 is retrieved and other gases. Thus the campaign data can be used for validation purposes of also other satellite measurements and model simulations.
- The results provide a comparative characterization of the participating instruments with respect to the TCCON instrument. The outcome of the campaign will be used for the further development of new observation sites to complement the TCCON network and improve support for the validation of the existing and future satellite missions and models.

2. INSTRUMENTATION

Institute	Instrument	Spectral range	Resolution	Species observed
FMI	Bruker 125HR	1800-15000	0.004 cm^{-1}	CH4, CO, CO2, H2O
Uni Bremen BIRA	Bruker Vertex70	2500-15000	0.16 cm^{-1}	CH4, CO, CO2, H2O
KIT	EM27/SUN	4000-9000	0.5 cm^{-1}	CH4, CO, CO2, H2O
Uni Wollongong	IR cube	4500-15000	0.5 cm^{-1}	CH4, CO2, H2O
RAL	Heterodyne	950/1280	0.002 and 0.02 cm^{-1}	CO2, H2O
Uni Groningen/ FMI	AirCore		13.4 mbar (AmbP>232 mbar)- 3.9 mbar (AmbP<232 mbar)	CH4, CO, CO2

6.1. TCCON observations



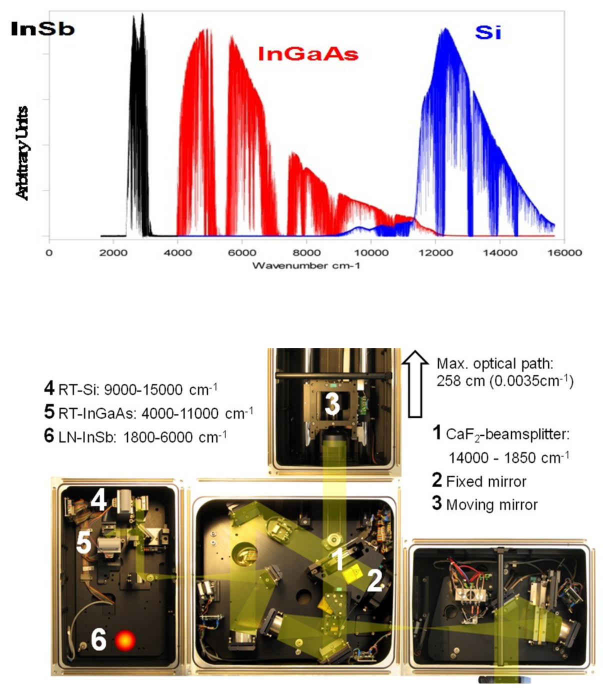
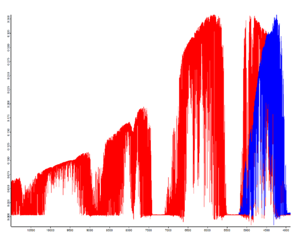


Figure 1: Left: TCCON sites. Right: Spectral coverage of the TCCON instrument at FMI Sodankylä, equipped with three channels. Optical diagram of the Bruker IFS 125HR spectrometer. 3 detectors are included: RT-Si; RT-InGaAs and LN-InSb.

6.2. Vertex 70



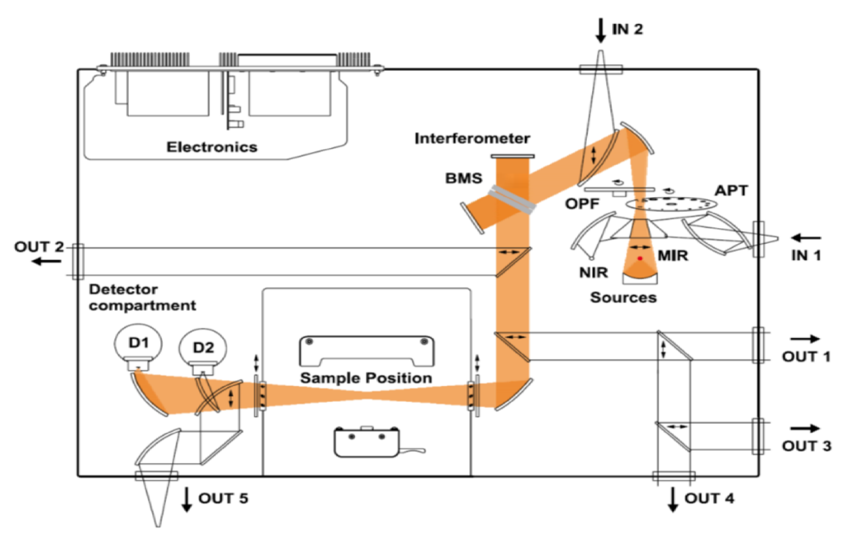


Figure 2: Left: Optical sketch of the Bruker Vertex70 spectrometer. The entrance IN 1 will be used for the solar absorption measurements. The optical entrance IN 1 of the spectrometer has been modified by the company in the way that the parallel light beam from the solar tracker is focused by a parabolic mirror on the entrance aperture APT (not shown here). Right: spectral coverage, RT-InGaAs and LN-InSb detectors.

6.3. EM27/SUN

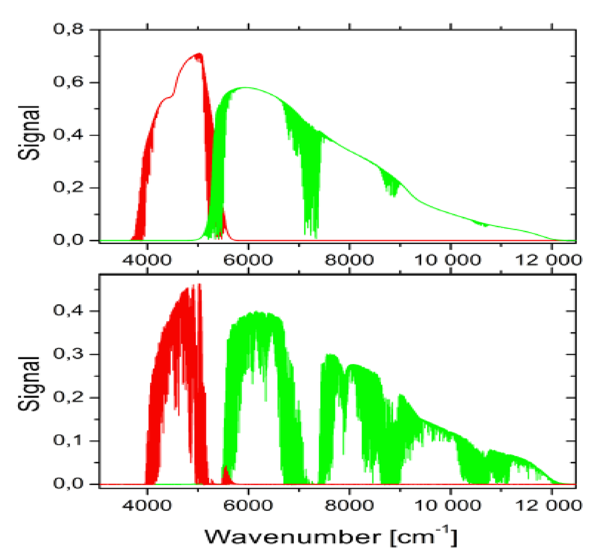


Figure 3: spectral coverage of the EM27/SUN equipped with two channels (top: lamp spectrum, bottom: atmospheric spectrum, from Hase et al., 2016).

6.4. IR Cube

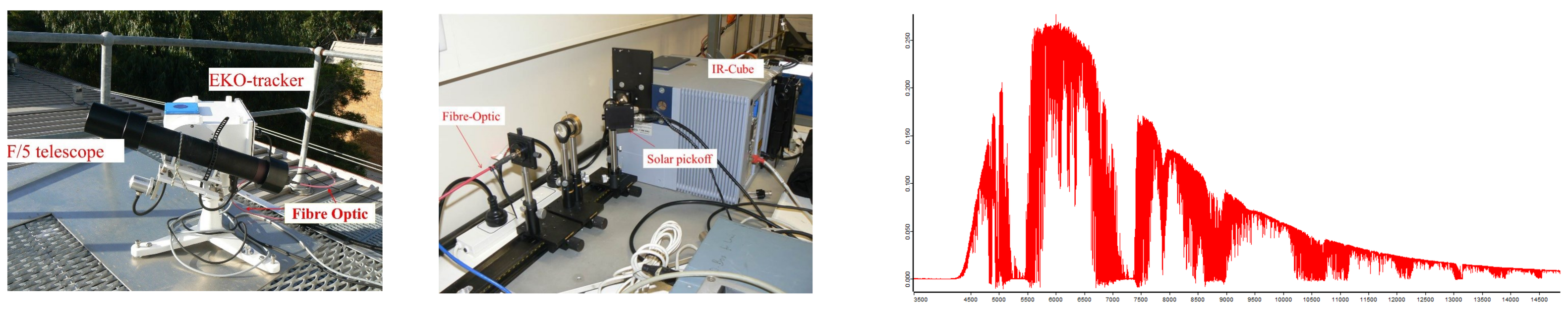


Figure 4: From left to right, a) the EKO-instruments solar tracker with telescope and fibre-optic, b) the solar beam input at the IR Cube end, c) a sample spectra (from May 15, 2017).

6.5. Laser heterodyne spectra-radiometer

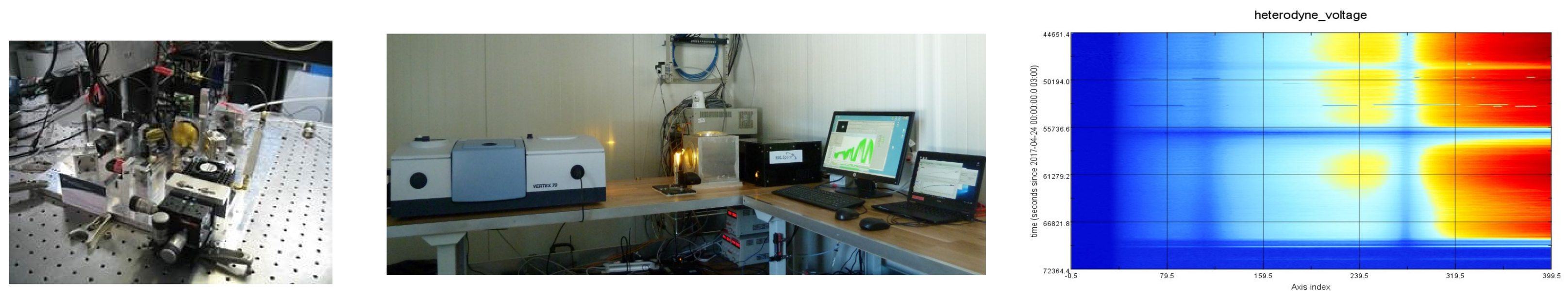
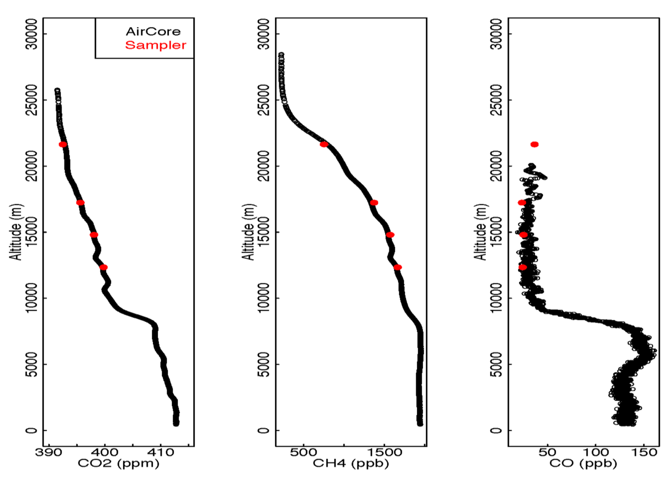


Figure 5: from left to right, LHR optical breadboard; LHR installation; H2O / CO2 spectra. A second step of miniaturization has seen the system shrunk to 40x40x20 cm without loss of performance. The system has been developed to operate quasi-autonomously.

6.6. AirCore Profiles

Figure 6: Validation of AirCore against sampler measurements. During the campaign in April 2017 independent 4 air samples were collected, vertical resolutions of each sample is 0.5-1.3 km at 12 - 22 km. AirCore is built as a stainless steel tubing of about 100m long, consisting of ~40 m of ¼" and ~60 m of 1/8" tube. A cavity ring-down spectrometer is used to analyse the samples. Two cylinders are used to calibrate the measurements to the WMO scales.



3. INSTRUMENT LINE SHAPE

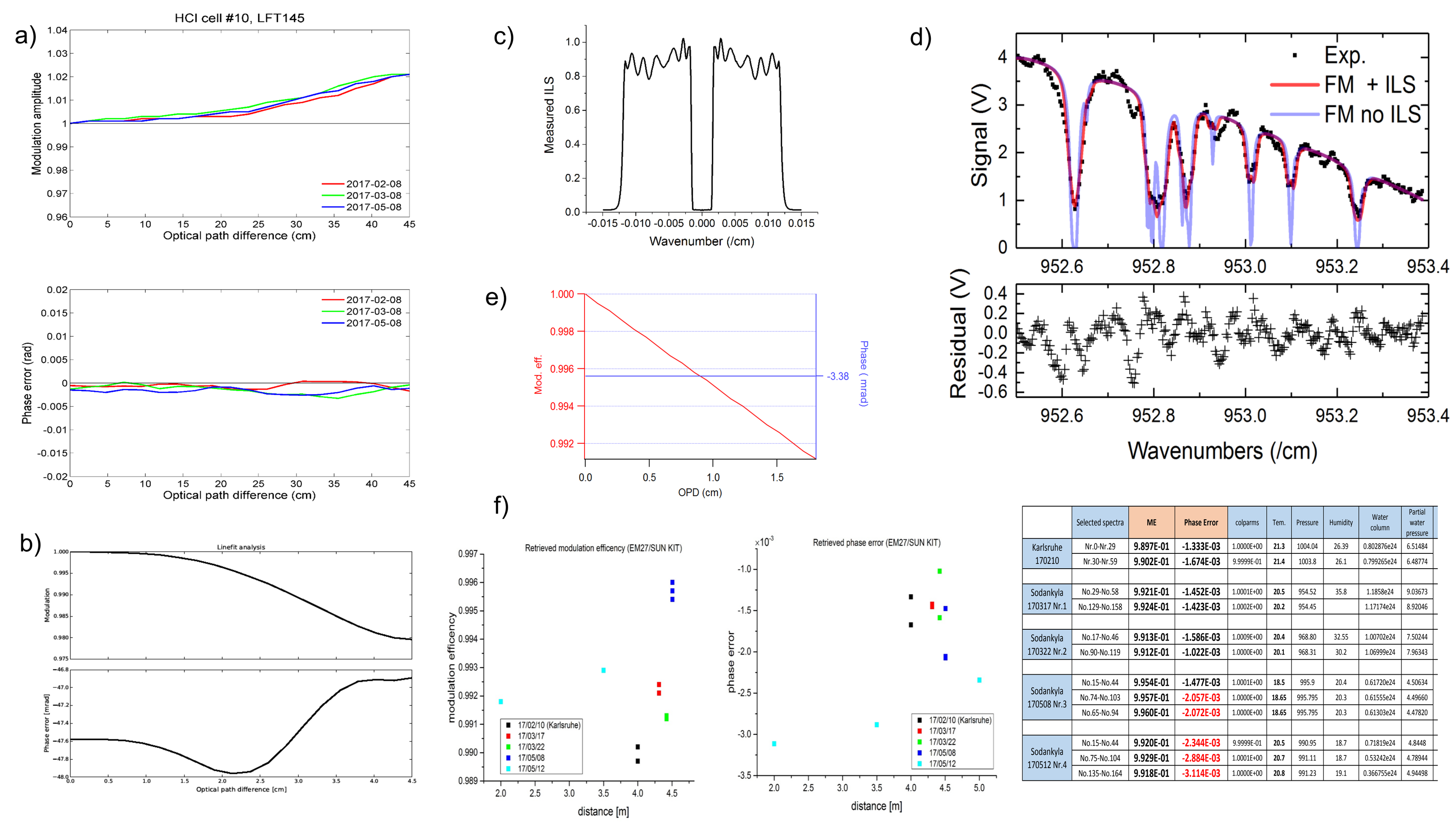


Figure 7: a) ILS time series of the TCCON instrument. HCl cell measurements are made using a NIR lamp and the ILS retrievals are done using LINEFIT14. The instrument has been pretty stable during the campaign; b) Vertex 70 Linefit analysis; c) LHR ILS defined by electronic filter transmission, measured using an RF generator; d) application of ILS to the forward transmission model (FM), 20 mbar of Ethane, 10 cm cell (note the lack of spectroscopic data (taken from HITRAN2012)); e) IR Cube ILS measurement; f) lamp measurements of the EM27/SUN.

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