Measurement of greenhouse gases from novel ground-based remote sensing instrumentations during the FRM4GHG campaign at the Sodankylä TCCON site

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Motivation for the project — Fiducial Reference Measurements for Greenhouse Gases (FRM4GHG)

- Greenhouse gas (GHG) measuring satellites require ground-based measurements for validation of temporal and spatial trends and/or dependencies on satellite observational characteristics.
- Total Carbon Column Observing Network (TCCON) provides accurate and precise measurements of GHGs and is the current standard for validation of GHG measuring satellites (e.g. SCIAMACHY, GOSAT, OCO-2, and upcoming S5P).
- TCCON network has limited geographic coverage, especially in remote locations and locations with high/low albedo.
- Limitations for TCCON — very expensive 400 - 500 k€, requires good infrastructure (container, Bruker IFS 125HR as spectrometer, solar tracker) - not easy to relocate, requires special operating conditions, requires trained personnel for both operation and maintenance
  — expensive if further expansion of the network is desired.

➢ Development of portable, easy to maintain and low cost systems for remote sensing GHG observations by several research institutes.

➢ These spectrometers have the potential to complement TCCON (see poster board #46 by Notholt et al.), however their performances have not yet been fully characterized.

Aim of the FRM4GHG project

- **Perform an intercomparison of simultaneously measured total column amounts of CO_2, CH_4, CO using several different portable low-cost spectrometric instruments under different atmospheric conditions in comparison to the TCCON instrument.**

Implementation of the FRM4GHG campaign

- Sodankylä TCCON site (67.37 N, 26.63 E, 188 m.a.s.l) has been selected for performing approximately one year of measurement campaign starting as of March this year.
- Participating groups and their respective instrumentations are listed below. In addition, regular Aircore launches are performed from the site, the data of which will be used to verify the calibration of the remote sensing instruments.

Instrument	Institute	Spectral range	Resolution	Main GHGs
Bruker IFS 125HR Fig. 1b-right	FMI	1800 — 15000 cm^{-1}	0.004 cm^{-1}	XCO_2, XCH_4, XCO @ 0.02 cm^{-1}
Bruker Vertex 70 Fig. 1c-left	Uni Bremen BIRA	2500 — 15000 cm^{-1}	0.16 cm^{-1}	XCO_2, XCH_4, XCO
Bruker EM27/SUN Fig. 1b-left	KIT	4000 — 9000 cm^{-1}	0.5 cm^{-1}	XCO_2, XCH_4, XCO
Bruker IR Cube Fig. 1d	Uni Wollongong	4500—15000 cm^{-1}	0.5 cm^{-1}	XCO_2, XCH_4
LHR (Laser Heterodyne Radoimeter) Fig. 1c-right	RAL	954—960 cm^{-1}	0.002 and 0.02 cm^{-1}	CO_2, H_2O
AirCore Fig. 1g	Uni Groningen FMI	In-situ sampling	13.4 mbar (Amb.P. > 232 mbar) 3.9 mbar (Amb.P. < 232 mbar)	CO_2, CH_4, CO vertical profiles, calibrated to WMO standards

Discussions

➢ Progress report on the early part of the project is presented here with a principal aim to identify and correct biases and errors between the participating remote sensing instruments.

➢ Most instruments have been operating well since their deployment. Except for two technical interventions: (1) the IR-Cube had its broken optical fiber cable replaced in April, and (2) the Vertex70 had an instrument modification in July thereby improving the instrumental line shape.

➢ XCO_2, XCH_4, XCO total columns retrieved from different instruments (as applicable) are compared with respect to the TCCON retrievals. EM27/SUN XCO_2 and XCH_4 values are scaled with calibration factors determined w.r.t the comparison measurements performed in Karlsruhe.

➢ XCO_2: EM27/SUN has the smallest bias relative to the TCCON. However, a small seasonal dependency is seen in the ΔXCO_2 values. Vertex70 shows better match w.r.t the TCCON for measurements done with the improved ILS. IR-Cube shows a change of bias (high bias) after the instrument intervention. LHR, which is a new homemade instrument, shows large discrepancies (very high bias) with diurnal variability relative to the TCCON.

➢ XCH_4: IRCube and EM27/SUN have very small bias relative to the TCCON. Vertex70 also has a small bias.

➢ XCO: Vertex70 has smaller bias w.r.t the TCCON as compared to the EM27/SUN.

➢ XAir: is an indicator of instrument performance. TCCON has a XAir value of about 0.98, the deviation from unity is mostly due to spectroscopic errors. Vertex70 shows better match w.r.t the TCCON for measurements done with the improved ILS. IRCube shows a higher bias pointing towards retrieval problems. Moreover, the step jump after the fiber cable replacement is not seen here.

Next steps and outlook:

— Comparison of retrieval results for the whole campaign duration and determination of the calibration factors w.r.t the TCCON. Verify calibration of remote sensing instruments w.r.t the Aircore. Identify source, understand, and correct the large bias observed with the new LHR instrument.

— Provide a significant dataset of GHG measurements which can be used for satellite validation purposes.

— Provide a guideline for further development of new observation sites to complement the TCCON network and provide better support for the validation of existing and future satellite missions.

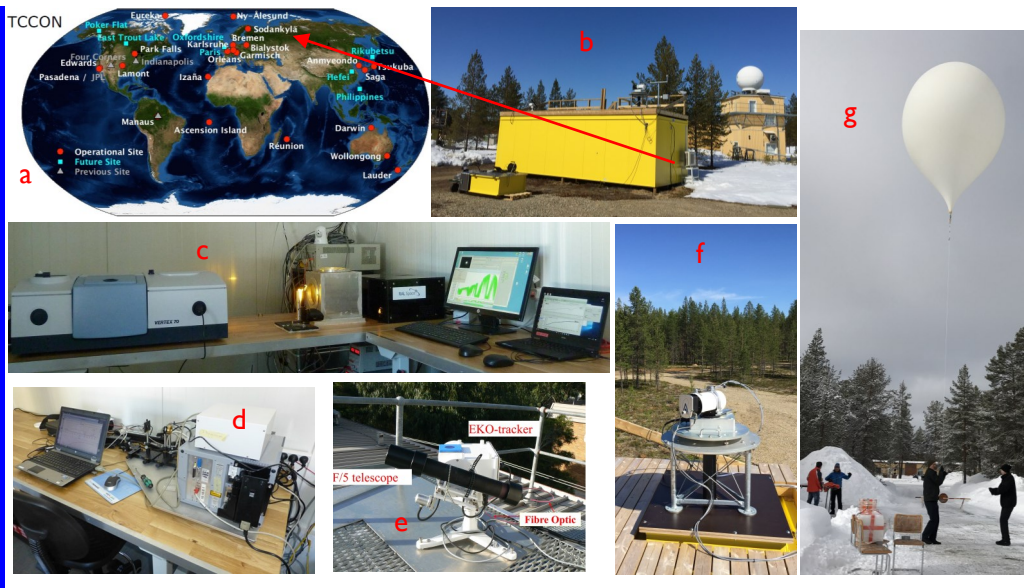
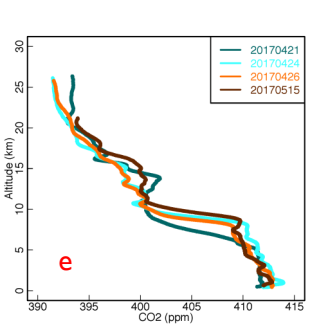
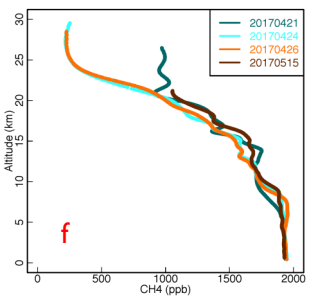
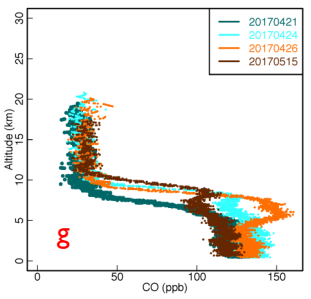
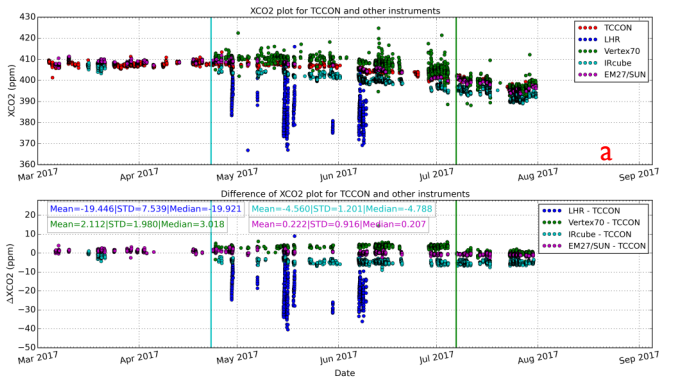


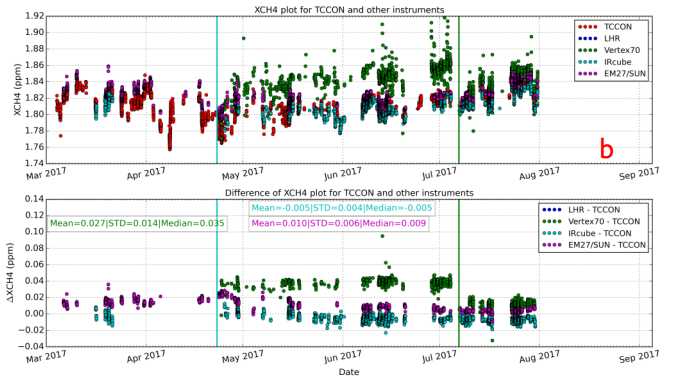
Fig. 1: (a) TCCON sites, (b) FRM4GHG container and EM27/SUN in front, (c-left) Vertex70 and (c-right) LHR, (d) IRCube, (e) suntracker for IRCube, (f) suntracker for Vertex70 and LHR, (g) Aircore launch at Sodankylä site

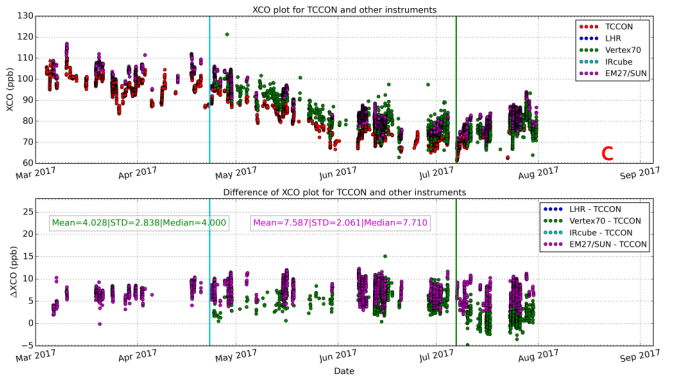












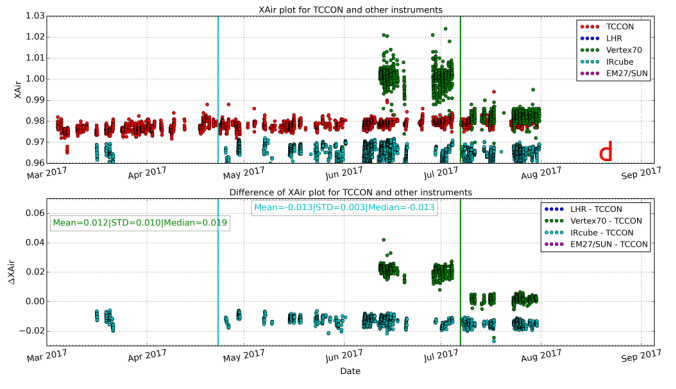


Fig. 2: (a-d—top panels) show the XCO_2, XCH_4, XCO, XAir, respectively, timeseries for all remote sensing instruments participating in the campaign. (a-d—bottom panels) show the difference of the respective products relative to the TCCON. The colored vertical lines correspond to the technical intervention for the respective instruments. (e-g) show the vertical profile of CO_2, CH_4 and CO, respectively, from the Aircore measurements performed during four different flights.

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