

Measurement of greenhouse gases from novel ground-based remote sensing instruments



the FRM4GHG campaign at the Sodankylä TCCON site, N. Finland

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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, GOSAT-2).
- 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, however their performances have not yet been fully characterized.

Aim of the FRM4GHG project

- Perform an intercomparison of simultaneously measured total column amounts of CO₂, CH₄, 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.
- Four portable spectrometers together with the TCCON are taking part in the campaign. 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.

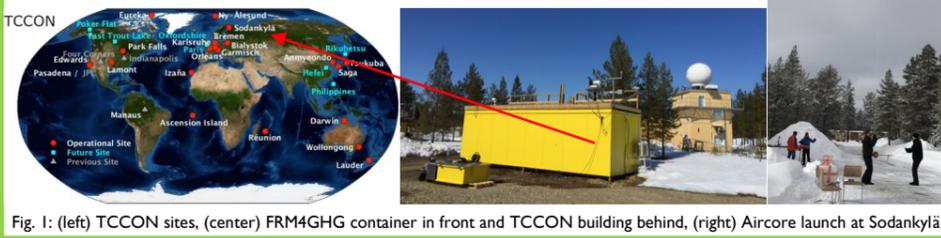


Fig. 1: (left) TCCON sites, (center) FRM4GHG container in front and TCCON building behind, (right) Aircore launch at Sodankylä

Aircore — University of Groningen / FMI

- In-situ sampling of CO₂, CH₄, CO to get vertical profiles of these gases calibrated to WMO standards. Resolution: 13.4 mbar (Amb. P. > 232 mbar), 3.9 mbar (Amb. P. < 232 mbar).

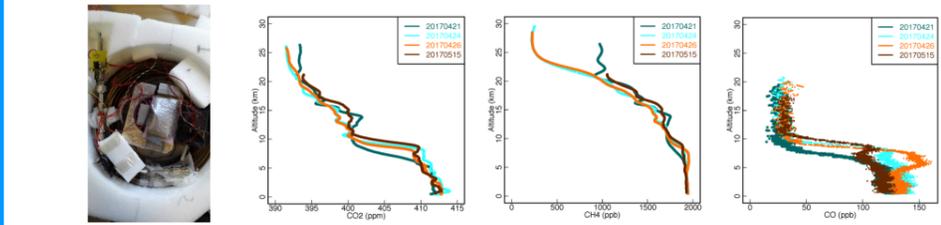


Fig. 2: (left-right) Aircore coil, vertical profiles of CO₂, CH₄ and CO from four different Aircore launch at Sodankylä TCCON site.

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.
- XCO₂, XCH₄, XCO total columns retrieved from different instruments (as applicable) are compared with respect to the TCCON retrievals. XAir which is a measure of the instrument performance is calculated from the O₂ total column and ground pressure measured independently.
- Most instruments have been operating well since their deployment. Five Aircore launches made.
- Vertex70: significant bias in ΔXgas values w.r.t TCCON till beginning of July, after instrument modification it has better ILS, resulting in comparable Xgas values relative to the TCCON. Bias in XAir is the smallest for Vertex70 compared to IRCube.
- EM27/SUN: stable ILS, the XCO₂ and XCH₄ values are scaled with pre-determined values derived from comparison measurements performed w.r.t another TCCON at Karlsruhe, bias in the scaled Xgas values are very small relative to the TCCON, however a small seasonality is observed in the ΔXgas plots.
- IRCube: stable ILS, optical fiber cable broke shortly after deployment which was replaced in April, XCO₂ values show a significant jump after instrument intervention, this is not so obvious for other species and also not seen in XAir, pointing towards a retrieval error for CO₂. XCH₄ bias is the smallest for IRCube compared to all other instruments.
- LHR: is a homemade relatively new instrument, XCO₂ shows large discrepancies (very high bias) with diurnal variability relative to the TCCON. Few days of data processed to check the newly developed retrieval algorithm, once the problem is cornered all data will be processed.

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.
- 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.

Affiliations

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Bruker IFS 125HR spectrometer (TCCON) — FMI

- Spectral range: 1800—15000 cm⁻¹, max resolution: 0.004 cm⁻¹, main species: XCO₂, XCH₄, XCO measured at 0.02 cm⁻¹. This is our reference instrument for the campaign.

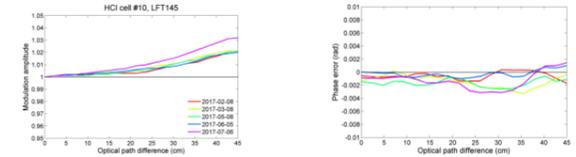
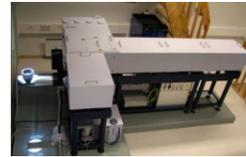


Fig. 3: (left) Bruker IFS 125HR at Sodankylä TCCON site, ILS parameters — modulation efficiency (center) and phase error (right) for the Bruker IFS 125HR.

Vertex70 — University of Bremen / BIRA

- Spectral range: 2500—15000 cm⁻¹, max resolution: 0.16 cm⁻¹, main species: XCO₂, XCH₄, XCO.

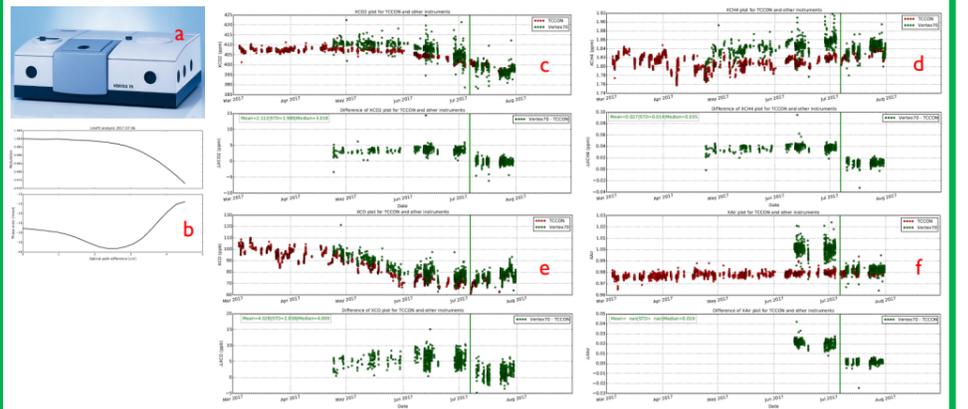


Fig. 4: (a) Vertex70, (b) ILS parameters plot for Vertex70, timeseries of XCO₂, XCH₄, XCO and XAir for the Vertex70 (green) and TCCON (red) (top panel of c-f) and the difference of Vertex70 relative to the TCCON (bottom panel of c-f).

EM27SUN — KIT

- Spectral range: 4000—9000 cm⁻¹, max resolution: 0.5 cm⁻¹, main species: XCO₂, XCH₄, XCO.

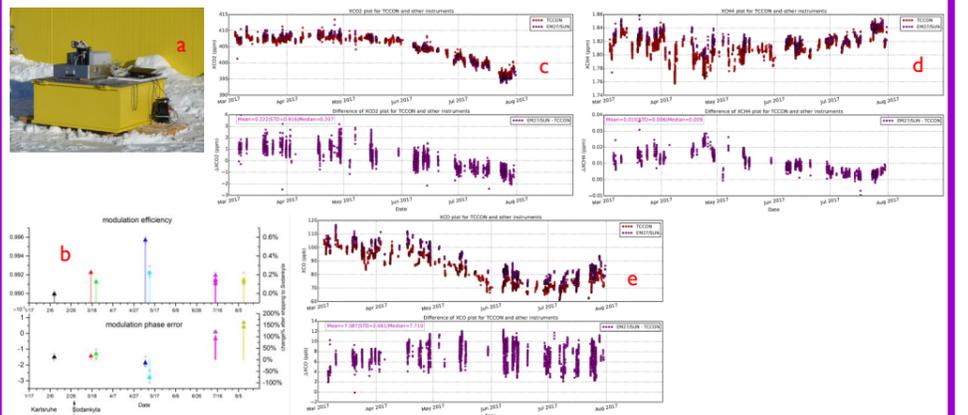


Fig. 5: (a) EM27/SUN, (b) ILS parameters plot for EM27/SUN, timeseries of XCO₂, XCH₄ and XCO for the EM27/SUN (magenta) and TCCON (red) (top panel of c-e) and the difference of EM27/SUN relative to the TCCON (bottom panel of c-e).

IRCube — University of Wollongong

- Spectral range: 4500—15000 cm⁻¹, max resolution: 0.5 cm⁻¹, main species: XCO₂, XCH₄.

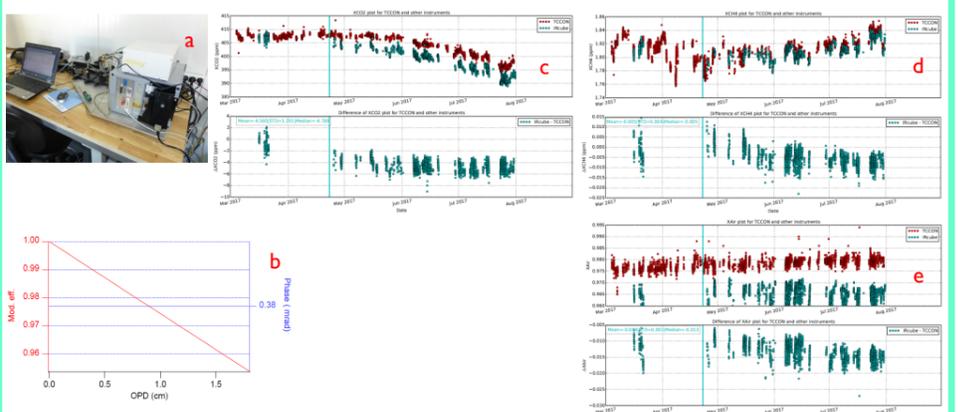


Fig. 6: (a) IRCube, (b) ILS parameters plot for IRCube, timeseries of XCO₂, XCH₄ and XAir for the IRCube (cyan) and TCCON (red) (top panel of c-e) and the difference of IRCube relative to the TCCON (bottom panel of c-e).

LHR (Laser Heterodyne Radiometer) — Rutherford Appleton Laboratory

- Spectral range: 954—960 cm⁻¹, max resolution: 0.002 and 0.02 cm⁻¹, main species: CO₂, H₂O.

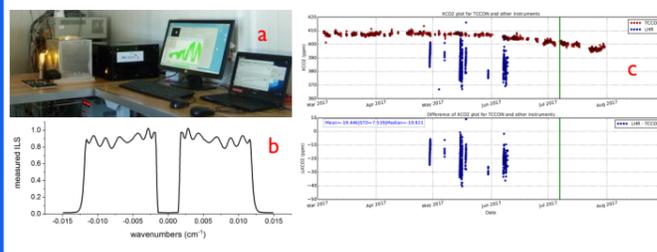


Fig. 7: (a) LHR, (b) ILS plot for LHR, timeseries of XCO₂ for the LHR (blue) and TCCON (red) (plotted in top panel of c) and the difference of IRCube relative to the TCCON (plotted in the bottom panel of c).

