Fiducial Reference Measurements for Greenhouse Gases (FRM4GHG) project status and updates

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FRM4GHG Overview and Objectives

Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations (FRM4GHG) is an ESA funded project focusing on: the intercomparison of instruments and harmonization of retrievals and products from collocated new and established GHG observation ground based Infrared instrumentations to get Fiducial Reference Measurements (FRMs) for Greenhouse Gases (GHGs). These dataset will also be used for the validation of satellite missions targeting:

- carbon dioxide (CO2)
- methane (CH4)
- carbon monoxide (CO)
- other climate relevant trace gases
TCCON (Total Carbon Column Observing Network) is the current state-of-the-art validation system for GHGs

- ~ 28 stations global distributed
- Fourier-transform infrared (FTIR) solar absorption spectrometer type Bruker IFS 125HR
FRM4GHG Overview and Objectives

• Assess characteristics of instruments in their capability to provide precise GHG column measurements

• Perform an intercomparison of simultaneously measured total column concentrations of a few GHG (CO$_2$, CH$_4$, CO) using several different portable low-cost spectrometric instruments collocated at a TCCON site where In-situ vertical profiles of GHG are provided by regular AirCore launches

• *Focus of the campaign on CO and CH$_4$ to support the Sentinel-5P validation*

• One of the outcome of the campaign will be to formulate a guideline for the further development of new observation sites to complement the TCCON network for example during dedicated validation campaigns for current and future satellite missions.
FRM4GHG: Project Schedule

- **Project start**: 8/16
- **Campaign begins**: 5/17
- **Campaign ends**: 10/17
- **Project end**: 1/18

**2016**
- Aug
- Sep
- Oct
- Nov
- Dec
- Jan

**2017**
- Feb
- Mar
- Apr
- May
- Jun
- Jul
- Aug
- Sep
- Oct
- Nov
- Dec
- Jan

**2018**

- **Container preparation and requirements identification**: 11/16
- **Intercomparison preparation**: 2/17
- **Intercomparison execution**: 3/17
- **Data analysis and corrective measures**: 10/17
- **Instrument packing**: 13/17

**Project management and project outreach**

- **Installation starts**: M8
- **Initial blind intercomparison results**: M9
- **Preliminary data delivery and comparison results**: M10
- **MI2 to MI5 data delivery and comparison results**: M11
- **MI2 to MI5 data delivery and packing**: M12
- **Instrument packing**: M13
- **M14**
- **M15**
- **M16**

- **Set-up & alignment**: 8/16
- **Updated comparison guidelines**: Apr
- **Comparison under optimised conditions**: May
- **Semi-blind intercomparison**: Jun

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FRM4GHG: The Sodankilä site

TCCON facility of the Finnish Meteorological Institute (FMI) in Sodankylä, Northern Finland 67.37°N, 26.63°E

TCCON facility is equipped with a Bruker IFS 125HR spectrometer and a large solar tracker A547N, it has been operational since early 2009.

The site also offers a balloon facility where AirCore and other sondes can be launched, AirCore analysis after each flight is performed at FMI.
FRM4GHG: The project team

J. Notholt, C. Petri (University of Bremen, IUP)
M. De Mazière, C. Hermans, F. Scolas, M. K. Sha (Royal Belgian Institute for Space Aeronomy)
R. Kivi, P. Heikkinen, Finnish Meteorological Institute
T. Blumenstock, F. Hase, Q. Tu (Karlsruhe Institute of Technology)
N. Jones, D. Griffith (U. Wollongong)
D. Weidmann, A. Hoffmann, M. Huebner (Rutherford Appleton Lab)
H. Chen, Joram Hooghiem (University of Groningen)

Project duration: August 2016 → end Jan. 2018

Funded by ESA, Technical Officer: A. Dehn assisted by P. Castracane
## FRM4GHG: The instruments overview

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Institute</th>
<th>Spectral range</th>
<th>Resolution</th>
<th>Main GHGs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruker IFS 125HR</td>
<td>FMI</td>
<td>1800 — 15000 cm(^{-1})</td>
<td>0.004 cm(^{-1})</td>
<td>XCO(_2), XCH(_4), XCO @ 0.02 cm(^{-1})</td>
</tr>
<tr>
<td>Bruker Vertex 70</td>
<td>Uni Bremen BIRA-IASB</td>
<td>2500 — 15000 cm(^{-1})</td>
<td>0.16 cm(^{-1})</td>
<td>XCO(_2), XCH(_4), XCO</td>
</tr>
<tr>
<td>Bruker EM27/SUN</td>
<td>KIT</td>
<td>4000 — 9000 cm(^{-1})</td>
<td>0.5 cm(^{-1})</td>
<td>XCO(_2), XCH(_4), XCO</td>
</tr>
<tr>
<td>Bruker IR Cube</td>
<td>Uni Wollongong</td>
<td>4500—15000 cm(^{-1})</td>
<td>0.5 cm(^{-1})</td>
<td>XCO(_2), XCH(_4)</td>
</tr>
<tr>
<td>LHR (Laser Heterodyne Radiometer)</td>
<td>RAL</td>
<td>954—960 cm(^{-1})</td>
<td>0.002 and 0.02 cm(^{-1})</td>
<td>CO(_2), H(_2)O</td>
</tr>
<tr>
<td>AirCore</td>
<td>Uni Groningen FMI</td>
<td>In-situ sampling</td>
<td>13.4 mbar (Amb.P. &gt; 232 mbar)3.9 mbar (Amb.P. &lt; 232 mbar)</td>
<td>CO(_2), CH(_4), CO vertical profiles, calibrated to WMO standards</td>
</tr>
</tbody>
</table>
Fiber-coupled to IRcube

BIRA suntracker- coupled to Vertex 70 and LHR
**FRM4GHG: The AirCore**

40 m (1/4” diameter) + 60 m (1/8” diameter); coils: 2.8 kg; Total package: 3.6 kg

<table>
<thead>
<tr>
<th>Flight no.</th>
<th>Month</th>
<th>Date</th>
</tr>
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<td>9</td>
<td>September</td>
<td>20170907</td>
</tr>
</tbody>
</table>

**CO₂**

**CH₄**

**CO**

**During the campaign**
FRM4GHG: Measurements (March – October 2017)

Observations status

Number of spectra

Date

- TCCON
- EM27/SUN
- Ircube
- vertex 70
- LHR
- AirCore
- TCCON LR
FRM4GHG: Intercomparison

- All teams deliver “incognito” – blind
  - For all measurement days and good spectra: column values for CO, CH4, CO2, H2O and O2; XCO, XCH4;
    (RAL provides only CO2 & H2O; IR-cube doesn’t measure CO.)
  - Instrument alignment measurements

- BIRA-IASB acts as the referee

- The following plots represents interim results - they are still being used for scientific papers
IRcube: new fiber cable installed for the solar tracker
Vertex 70: installation of additional aperture in the parallel beam
EM27/SUN: a priori change from KA to SOD to TCCON map files
FRM4GHG: comparison (interim) results – XCO4
FRM4FGHG: Comparison results - summary

• Most instruments have been operating well since their deployment

• The data intercomparison was carried out starting from June, this already triggered an understanding on possible improvements on the instruments set-ups (some already implemented)

• Nine AirCore launches made

• Very good agreement for Vertex70, EM27/SUN, IR Cube wrt the TCCON reference

• LHR presented significant bias – it is a prototypal instrument and works are in progress

• Final results still have to be delivered they will include AirCore measurements and analysis
FRM4GHG : Next Steps

- Comparison of retrieval results for the whole campaign
  - Determination of calibration factors w.r.t TCCON
  - Verify calibration of remote sensing instruments w.r.t the AirCore
  - Identify sources, understand, and correct the biases observed with the instruments

- Provide a significant dataset of GHG measurements which can be used for satellite validation purposes. This will be one of the main target for the planned extension of the project in particular for Sentinel-5P validation.

- 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
FRM4GHG Access to information, data and results

http://frm4ghg.aeronomie.be

→ Results (for now for internal use only)
→ Outreach
→ Pictures
→ Campaign blog
→ Follow on twitter: #frm4ghg
Thank you!