

ESA GHG Cal/Val with outlook to Copernicus Contributing Missions

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CEOS AC-VC-19 / ACSG Joint Meeting 2023, Brussels

Overview

- Sentinel-5P Fiducial Reference Measurements (FRM) overview
- FRM4GHG status update
- ESA COCCON activities
- Outlook: Copernicus Contributing Missions - CH4 Cal/Val

Sentinel-5P ESA FRM and Cal/Val activities



POp 1 and POp 2 (Pandonia Operations) – operational support 2018-2022 & 2022-2027

FRM4AQ (FRM for Air Quality) - development and evolution to PGN 2018-2022 & 2023-2025 +2y

FRM4GHG (1 and 2) - R&D 2016-2020 & 2021-2025

FRM4DOAS (1 and 2) - R&D 2016-2020 & 2021-2025

COCCON PROCEEDS - (FTIR EM27/SUN) development/pre-ops 2017-2023
COCCON OPERA - operational support 2023-2027

Other FRMs: EVE <https://evelidar.eu/about/> ; DIVA <http://diva.inoe.ro/>
FRM4RADAR <https://geomet.uni-koeln.de/forschung/frm4radar>



Sentinel-5P ESA FRM and Cal/Val activities



ESA open tenders (funded through Copernicus) to be published Q1 2024:

2024-2027

FRM support in scope for S5p validation for 4 years duration:

i) **GHG ground based FTIR/TCCON/NDACC**

-> timely availability of CO, CH₄, HCHO

ii) **FRM4DOAS operational implementation**

-> central processing, harmonised data sets

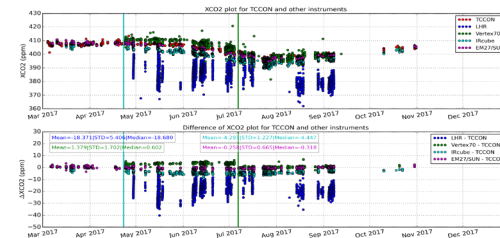
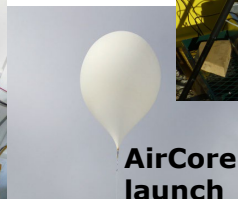
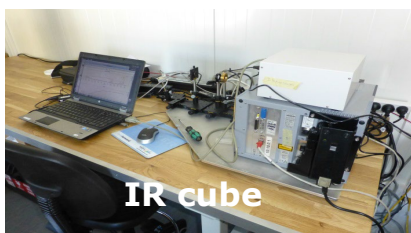
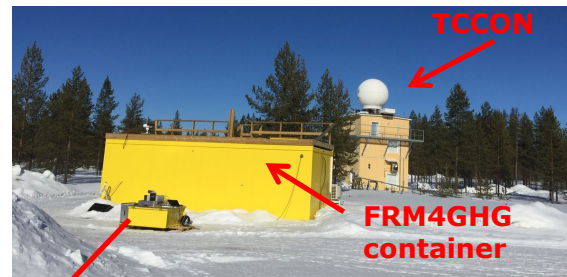




FRM4GHG 1 during 2016-2020

IUP Bremen, BIRA-IASB, KIT, FMI, Uni Groningen, Uni Wollongong, RAL

- Inter-comparison of ground based transportable FTIR systems with reference to TCCON as standard system – measurement campaign in Sodankyla/Finland
- Provide a guideline for further development of new observation sites to complement the TCCON network
- Target Products: CO, CO₂, CH₄ (HCHO)



Intercomparison of low and high resolution infrared spectrometers for ground-based solar remote sensing measurements of total column concentrations of CO₂, CH₄ and CO

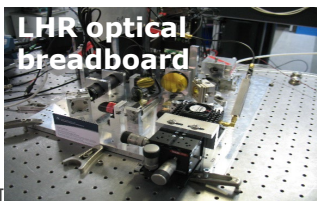
Mahesh Kumar Sha¹, Martine De Mazière², Justus Notholt³, Thomas Blumenstock⁴, Huilin Chen⁵, Angelika Dehn⁶, David W T Griffith⁷, Frank Hase⁸, Pauli Heikkinen⁹, Christian Hermans¹⁰, Alex Hoffmann¹¹, Marko Hoebner¹², Nicholas Jones¹³, Rigel Kivi¹⁴, Rovo Langerock¹⁵, Christof Petri¹⁶, Francis Seckler¹⁷, Qiansi Tu¹⁸, and Damien Weidmann¹⁹

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FRM4GHG 2 during 2021-2025

Objectives:

- **Improve instruments of low-resolution spectrometers** that have been assessed in previous FRM4GHG project (EM27/SUN, Vertex-70, IRcube, LHR), including:
 - Enclosure more mobile and standalone version of the LR FTIRs
 - solar tracker based on fiber optics (EM27/SUN, IRCube,...)
 - develop additional AirCore observations of new species (N₂O and OCS in addition to CO₂/CH₄/CO)

- **Evolve algorithms**, including:
 - HCHO retrieval optimisation from LR FTIRs
 - Improvements and extensions to PROFFAST and updates of associated spectroscopic linelists, line-mixing and speed dependent Voigt schemes
 - Implementation of modifications/extensions to PREPROCESS and PROF-FAST for Vertex70, IRcube, and other low-resolution spectra

- **Address network harmonization** (TCCON and COCCON), including:
 - Development and demonstration of EM27/SUN travel standard
 - Develop rapid delivery of GHG data for satellite validation from LR NIR spectra, procure NRT ECMWF P/T profiles and their use as dual option in PROFFAST, use CAMS as prior, co-ordinate with TCCON for using NRT ECMWF P/T profiles

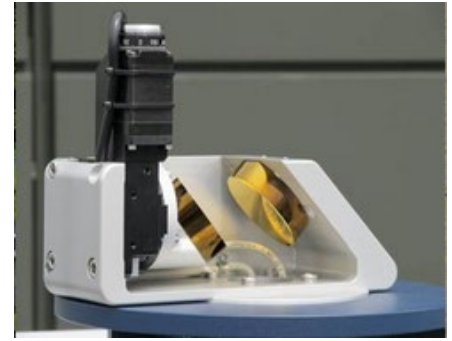
ESA FRM development and operation –



<https://www.imk-asf.kit.edu/english/COCCON.php>
KIT (Karlsruhe Institute for Technology)

COCCON PROCEEDS: September 2017 – March 2023:

FTIR spectrometer EM27/SUN –
Prototype for centralised data collection and processing facility at KIT (Karlsruhe)



Objectives:

- CO, CO2, CH4 Spectra generation from the raw interferograms
- Perform a quality screening for discarding invalid spectra
- Create a web interface and a storage facility
- Demonstration of the validity of the workflow and of the generated spectra by performing a quantitative spectral analysis (retrieval of column-averaged trace gas abundances from a test set of uploaded spectra)



ESA FRM development and operation –

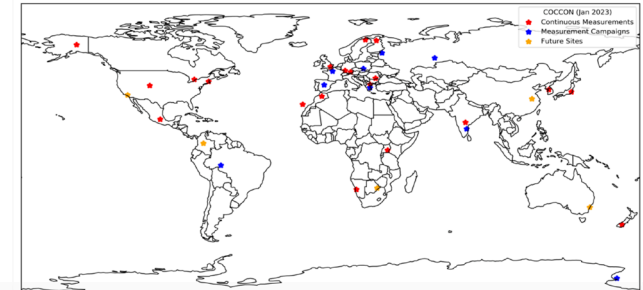
<https://www.imk-asf.kit.edu/english/COCCON.php>

Operational contract **COCCON OPERA 2023 - 2027**

- Network processing Operations, including:
 - central processing,
 - data dissemination to EVDC, <https://evdc.esa.int>
 - GEOMS Format,
 - COCCON Web services,
 - Network operation and reporting,
 - set up of ca 6 EM27/SUN instruments in Spain (collaboration AEMET)
 - Regular COCCON meetings with Pis (ca. bi-monthly)
 - Training on limited scale (best effort)
- R&D: COCCON instrument evolution
C2H2 gas cells as additional tool for calibration of COCCON spectrometers.

COCCON Data Repository

Operational Sites and Measurement Campaigns



Operational Sites

COCCON Site		EM27SUN	Coordinates	Data Download
Anmyeondo, South Korea	NIMS	SN184	Lat = 36.53° Lon = 126.52° Alt = 47 m	
Boulder, Colorado, USA	NOAA	SN080	Lat = 39.91° Lon = -105.26° Alt = 1650 m	2021-03-08, 2021-10-29, Boulder CF (Rev. 01)
Cambridge, Massachusetts, USA (Harvard Forest)	HARVARD	SN046	Lat = 42.533° Lon = -72.190° Alt = 359 m	2018-05-14, 2019-12-11, Harvard Forest CF (Rev. 01)
Cedre Gouraud Forest, Morocco (Atlas-Mohammed V)	LSCE/AtlasM5	SN103	Lat = 33.405° Lon = -5.103° Alt = 2072 m	2019-09-17, 2019-10-14, AtlasM5 CF (Rev. 01)
Daejeon, South Korea	KRISS	SN206	Lat = 36.39° Lon = 127.359° Alt = 72 m	
Fairbanks, Alaska, USA	UAF	SN050	Lat = 64.8590° Lon = -147.8500° Alt = 212 m	2018-04-07, 2018-10-18, Fairbanks CF 2019-03-11, 2019-10-17, Fairbanks CF 2021-04-18, 2021-11-05, Fairbanks CF (Rev. 01)
Gobabeb, Namibia	GNRI	SN051	Lat = -23.5611° Lon = 15.9414° Alt = 410 m	2017-01-09, 2020-11-27, Gobabeb CF (Rev. 01) 2017-01-09, 2020-11-27, Gobabeb CF (Rev. 02) 2017-01-09, 2021-04-21, Gobabeb CF (Rev. 02)

Example: Validation of S5P Carbon Monoxide with COCCON

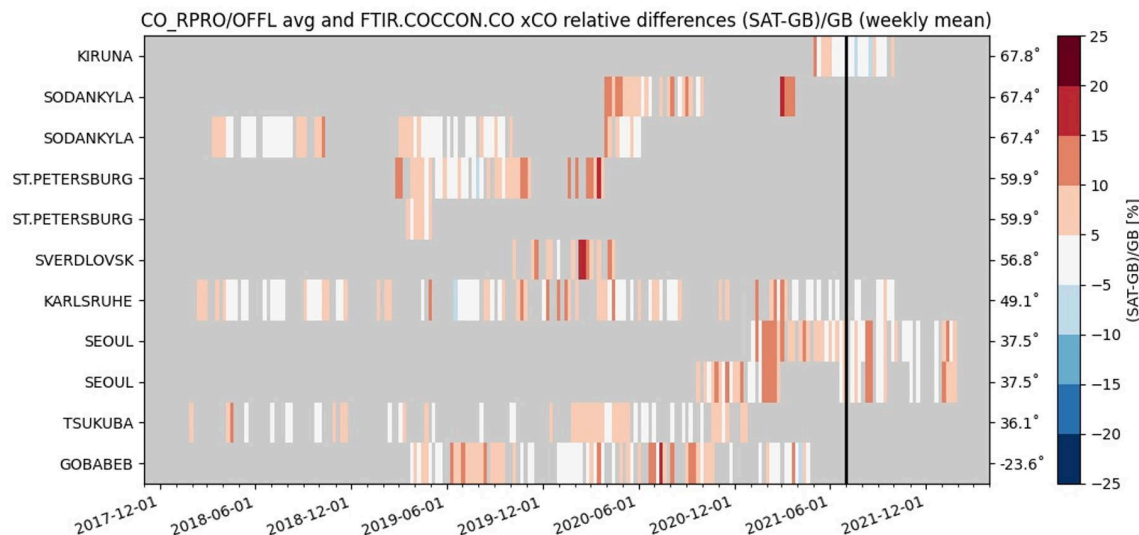


L2_CO (B. Langerock, M.K. Sha)

Validation using COCCON data

Data set 2018 – 06/2022

Relative difference
S5P-COCCON/COCCON
(Weekly mean)



Mean → Bias = 6.08% ; STD = 5.32% ; correlation coefficient = 0.91



Copernicus Contributing Missions - background



2022: Call for Contributing missions including Atmosphere domain for the first time

2023 May: Two satellite providers for atmospheric CCM selected, KO with ESA (in Copernicus Frame)

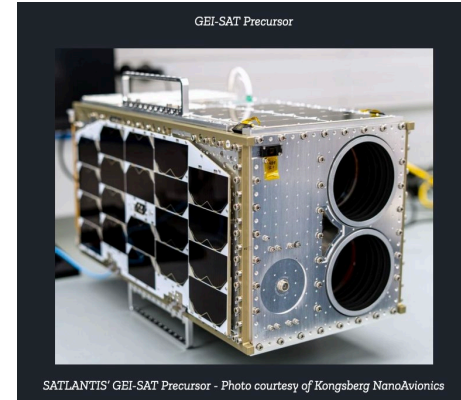
Classified as “emerging” CCMs (new space start-ups)

- **Absolute Sensing (France)**, GESat, Cryogenic MCT Spectro-imager
 - initial focus: **CH4 data product** , later also CO2 (2025)
 - Small satellite: 100kg, 1st launch July 2024, 24 satellites by 2027
 - Spatial resolution 50 m , daily measurement on area of interest,
 - Emission detection threshold >50kg/h
 - Dedicated Quality Control and Cal/Val tasks

- **SATLANTIS (Spain)**, GEI-SAT, iSIM-go VNIR-SWIR, camera

<https://satlantis.com/gei-sat-constellation/>

- **CH4 data product**, methane emission detection
- Objective: Oil&Gas industry (collaboration with Enagas)
- MicroSat: ca. 17kg, launch 12 June 2023 (precursor satellite),
 - Constellation of 3 MicroSats launch 2025/26
- nominal life-time 4 y
- Spatial resolution 13m
- Dedicated Quality control and Cal/Val tasks



Atmospheric MPC – so far dedicated to S5P only, will be tasked to provide support to CCMs

- New ATM MPC tasks, KO November 2023 relative to CCMs SATLANTIS and Absolute Sensing:
 - Provide guidance to CCMs on QC and Cal/Val tasks, based on long years of expertise in this field
 - Review of CCM documentation – e.g. Cal/Val reports, ATBDs etc.
 - Independent QC checks of sample data sets of CCMs
 - Independent validation for sample data sets
- Challenges:
 - Validation methods not yet developed by ATM MPC, strategies to be set up
 - Insufficient access to high resolution reference data