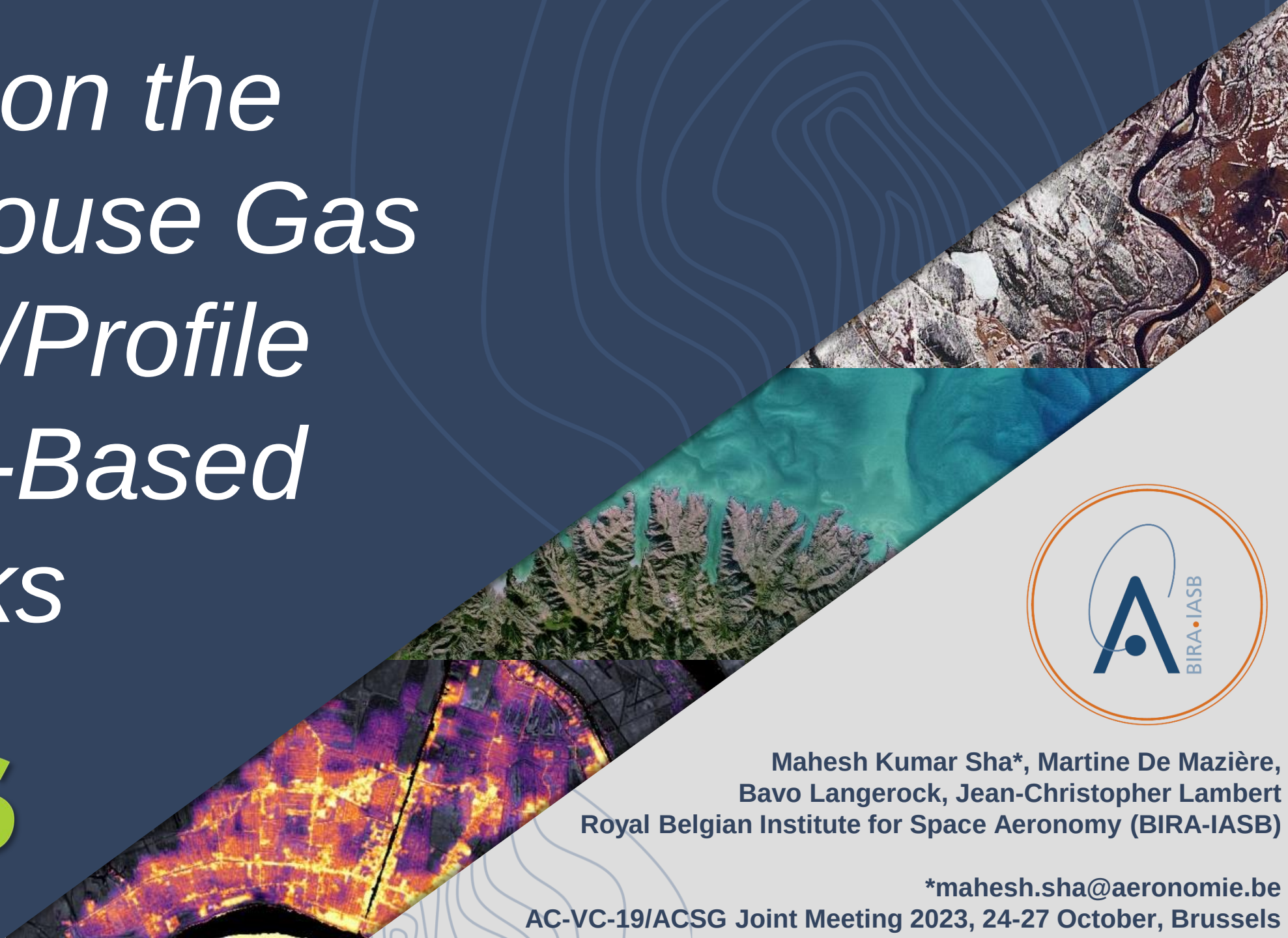
Update on the Greenhouse Gas Column/Profile Ground-Based Networks



Committee on Earth Observation Satellites

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Status and issues of the GHG Networks

ROADMAP FOR IMPLEMENTATION OF A CONSTELLATION ARCHITECTURE FOR MONITORING CARBON DIOXIDE AND METHANE FROM SPACE - ANNEX C - CV-5

CV-5 Identify gaps and suggest improvements in ground-based and airborne validation infrastructure (i.e. geographical / geophysical gaps for FRM) and other long-term validation needs (at horizon 2025-on)

→ Reported here: analysis of information shared at NDACC-IRWG-TCCON-COCCON Annual Meeting 2023, Spa, Belgium

https://events.spacepole.be/e/ndacc-irwg-tccon-coccon-annual-meeting-2023

GHG Column/Profile Cal/Val Networks

NDACC FTIR

http://ndacc.org

- Bruker 120HR/125HR
- Resolution 0.0036 cm^{-1}
- Spectral range: SWIR, MIR and TIR
- Measurements every ±10'
- 21 stations worldwide

- Targets: O_3, CH_4, N_2O, (CO_2, HCHO, SF_6, CFC, HCFC, H_2O, HDO not official), CO, HNO_3, HCl, HF, HCN, C_2H_6, $ClONO_2$, (C_2H_2, PAN, OCS, CH_3OH, NH_3, HCOOH, NO_2 not official)

- Profile retrievals (low vertical resolution, typically tropo/strato separation)
- Retrieval software: SFIT or PROFFIT
- Measurement protocol (SOP), no central processing, QA/QC for selected targets in CAMS operational validation

TCCON

https://tccondata.org/

- Bruker 125HR
- Resolution 0.02 cm^{-1}
- Spectral range: SWIR
- Measurements every ~ 3'
- 28 stations worldwide

- Targets: CO_2, CH_4, N_2O, H_2O, HDO, CO, HF

- Profile scaling retrievals (profile retrievals in development)
- Retrieval software GGG
- Central QA/QC

COCCON

http://www.imk-asf.kit.edu/english/COCCON.php

- Bruker EM27/SUN
- Resolution 0.5 cm^{-1}
- Spectral range: SWIR
- Measurements every ~ 1'
- > 60 instruments worldwide (some fixed sites but mostly for campaigns)

- Targets: CO_2, CH_4, CO, H_2O

- Profile scaling retrievals

- Retrieval software PROFFAST
- Central calibration & processing facility at KIT

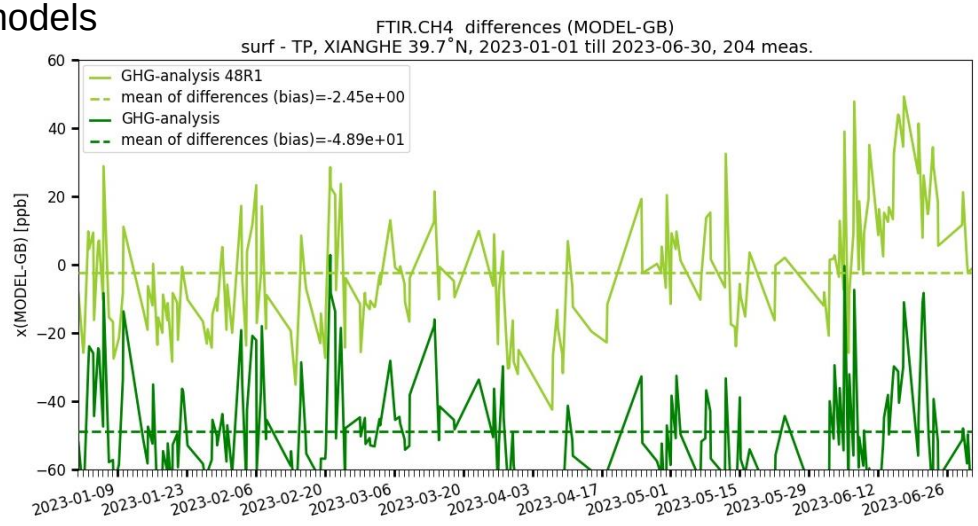
I. Availability of FTIR data for Cal/Val: AS IS

- Growing awareness for importance and successful use of NDACC-IRWG,TCCON and COCCON data for satellite validation and model evaluation in various programmes: OCO-2/3, GOSAT series, ESA/Copernicus ATM-MPC, EUMETSAT AC-SAF, CO2M validation, TANSAT, Copernicus services (CAMS, C3S), ESA CCI (ozone, GHG, ozone & aerosol precursors)…

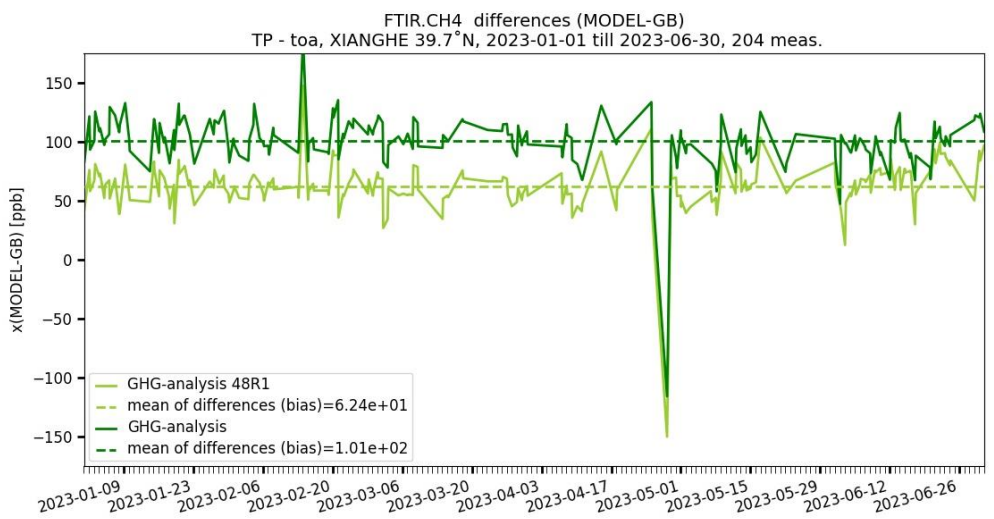
E.g., FTIR data used for model validation (reanalysis, o-suite forecasts, GHG o-suite analysis and high-resolution forecasts, e-suite analyses at ECMWF, …)

Example of a CH_4 comparison at Xianghe (China): bias between FTIR data and two different models

CH4 tropo- column comparison



CH4 strato- column comparison



I. Availability of FTIR data for Cal/Val: ISSUES

- NDACC PIs get (limited) financial support through Copernicus (ECMWF) and ESA *(to complement funding)* via CAMS-27 project for rapid data (*RD*) delivery (<1 month instead of yearly) of target species: CH_4, CO, O_3 and H_2CO. *Funding for RD secured until 2026/Q1.*

- NDACC – Europe embedded in research infrastructure ACTRIS for more sustainable support by Member States, *but for now limited to a few target species (no long-lived GHG) and very few stations.*

  A central data processing and data delivery system (CDPS) will benefit NDACC-FTIR partners in ACTRIS.

Rapid & continuous data delivery remains a problem, especially for TCCON data

cf. governance of research network type, with various funding mechanisms

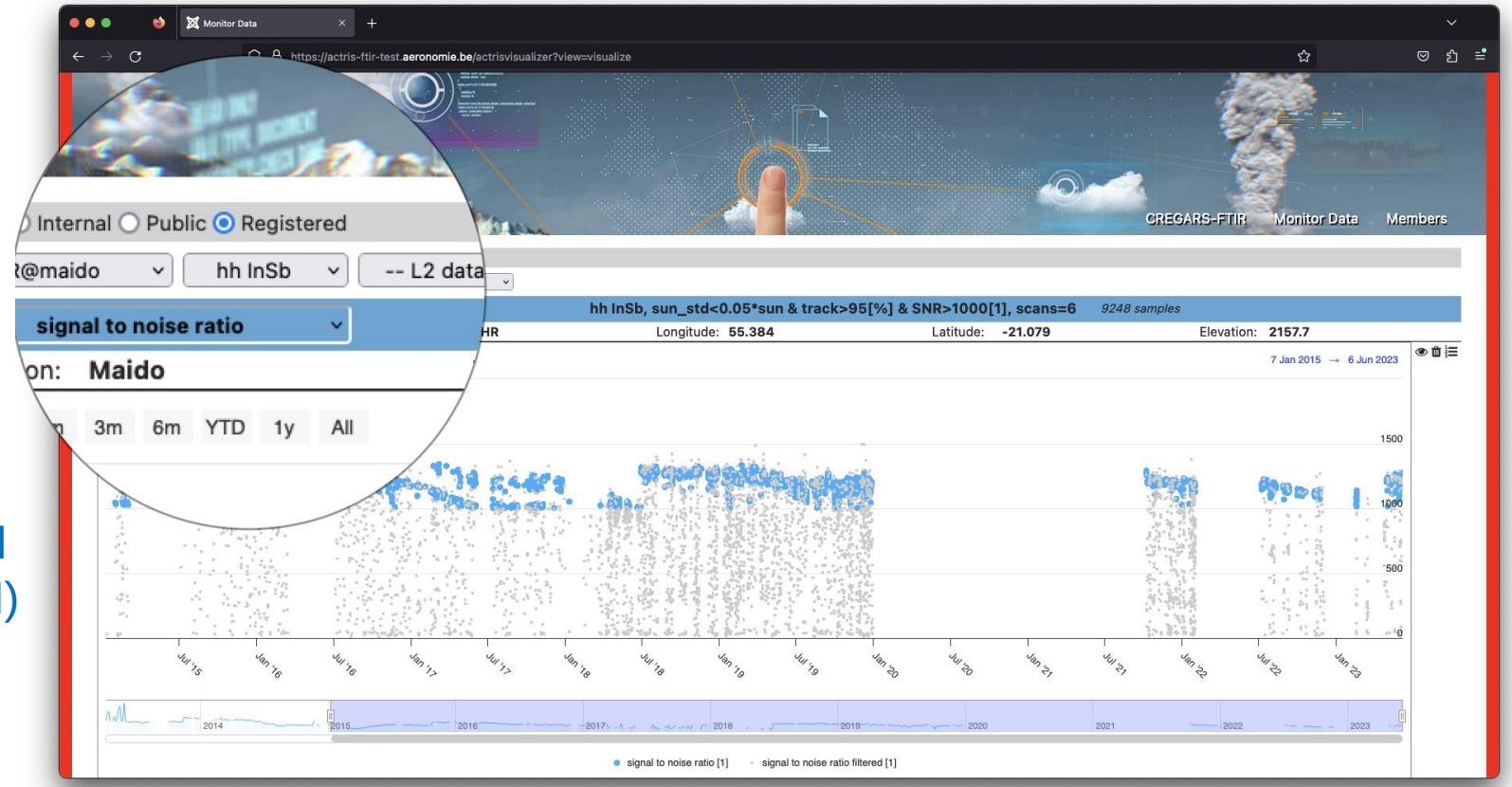
cf. maintenance of data acquisition infrastructure is costly, a burden for operators, hampered by delays when ordering spare parts…

cf. each individual TCCON PI is responsible for the whole data production chain using the standard TCCON data processing code; data QA/QC is done by a group of people where an editor and two reviewers are assigned to each site.

cf. embedding of TCCON-Europe is still pending, not supported by all

II. Access to FTIR data for Cal/Val: AS IS

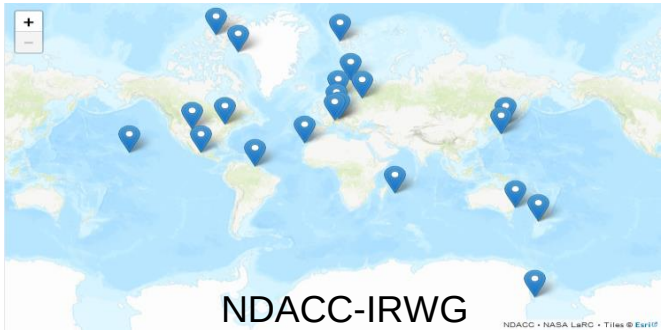
- Consolidated (fully QA/QC-ed) FTIR GHG data are available from dedicated datacentres (NDACC DHF, TCCON data archive, EVDC for COCCON) in standard formats, at latest one year after data acquisition (official protocol)
- ACTRIS CDPS includes QA/QC and L1 & L2 data visualization tools; https://actris-ftir.aeronomie.be



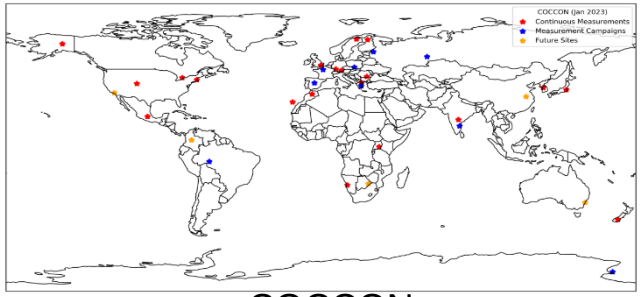
No common approach for now for all (NDACC-IRWG, TCCON, COCCON) FTIR data

III. FTIR data coverage for Cal/Val: AS IS

Permanent stations


NDACC-IRWG

TCCON



COCCON

- New planned sites: Porto Velho, Brazil; Yucatán Peninsula, Canadian High Arctic Research Station (CHARS)
- Number of (LR) spectrometers growing every year
- Permanent installations of LR spectrometers in array (by groups from: TUM - Germany, UoT + EC – Canada, French groups, AEMET – Spain, UK)
- New cal/val planning and ground-based network design website https://co2m.aeronomie.be/ : cal/val support for CO2M Product Validation and Monitoring and extendable to related missions, website also enables joint visualization of satellite L3 files and global or regional emission inventories

Campaigns

- Several campaign activities performed by various groups (targeting cities, coal mining areas…); some supported by ESA SVANTE project (Kolkata (India); Jinja (Uganda); …) https://s5pcampaigns.aeronomie.be/
- New activities planned with shipborne measurements, AOD retrievals, open path measurements, ...

III. FTIR data coverage for Cal/Val: ISSUES

- Lacking validation data over high albedo regions – current TCCON sites cover albedo of ~ 0.4, spectrally less smooth locations are required, lacking validation data over oceans
- Wish list for stations at SMO, Bouvet Island, Alice Springs, Riyadh – regions with large biases in OCO-2 data compared to models
- Better coverage needed in S-E Asia because of important contributions to global CO_2 budget
- Access to campaign data not optimal (application of FAIR principles recommended)
- Continuation of measurements at successful and highly relevant campaign sites?
- Mid- to long-term and /or mobile deployment of LR spectrometers requires automation and an appropriate enclosure for hosting the FTIR system and its accessories: several individual groups are developing one but currently without a common approach and without 'commercialization' in view.
- Required coverage may be different depending on focus on anthropogenic/biogenic emissions, large point sources, or else…

IV. FTIR data quality (accuracy, precision, homogeneity) for Cal/Val: AS IS

- TCCON GGG2020 released (few sites still missing, datasets are being extended) with many improvements over GGG2014
  - new approach to generate a priori trace gas profiles for CO2, CH4, CO, N2O and HF,
  - prior improvement, but some remaining issues with prior profiles (CO in high polluted regions – e.g., California, Xianghe, CH4 in stratosphere)
  - Update in telluric and solar spectroscopy, added non-Voigt line shapes for some species,
  - update from noontime NCEP meteorology to 3-hourly GEOS FP-IT meteorology,
  - new retrieval vertical grid to better resolve surface gradients,
  - per window airmass dependent correction rather than per-gas,
  - two new CO2 windows reported separately which have quite different vertical sensitivity compared to standard CO2,
  - additional in-situ profiles used to tie to the WMO scale, CO is not tied to WMO scale,
  - non-linearity correction applied to data from many sites which improved the overall quality of TCCON data significantly,
  - additional diagnostics to flag out-of-family data in the QC process
- NDACC provides profile retrievals (limited DOF); TCCON profile retrievals have been demonstrated for CH_4 but not yet implemented as standard in TCCON
- Current TCCON error budget (precision): XCO2 = 0.5 ppm (<0.15%), XCH4 = 5 ppb (<0.3%), XCO = 2 ppb (<2%))
- COCCON data processing improved from PROFFAST to PROFFAST2
- Concept of travelling standard to improve intra-network and inter-network (COCCON tied to TCCON) consistency

IV. FTIR data quality (accuracy, precision, homogeneity) for Cal/Val: ISSUES

- Higher precision still needed: goal is to achieve precision XCO2 = 0.2 ppm, XCH4 = 4 ppb and XCO = 1 ppb
- Mutual consistency within and between networks not good enough yet
- Formal GGG/PROFFAST intercomparisons needed
- Deployment of travelling standard currently (too) limited because of limited resources (ESA FRM4GHG-2)
- No travelling standard yet for connecting TCCON data to NDACC-IRWG data
- Additional in-situ profiles are used to tie TCCON to the WMO scale, but CO is not yet tied to WMO scale,
- AirCore data are the best source for verification/improving a priori vertical profiles: currently there is no central archive of all available AirCore data (mainly NOAA and French/AERIS AirCore data archives)
- Deployment of AirCore not yet fully ‘operational’ and not feasible at all sites (cf. problem of recovery). A remotely controlled/automatic glider-borne AirCore does exist at NOAA but is not widely available.
- NDACC-IRWG not yet tied to WMO scale; travelling standard for NDACC could support this ‘calibration’
- Do we know requirements for validating GHG emissions (in addition to concentrations)? Need for a new Cal/Val methodology?