Karlsruhe Institute of Technology

CO2 COCCON
Collaborative Carbon
Column Observing Network

The Collaborative Carbon Column Observing Network overview and current status

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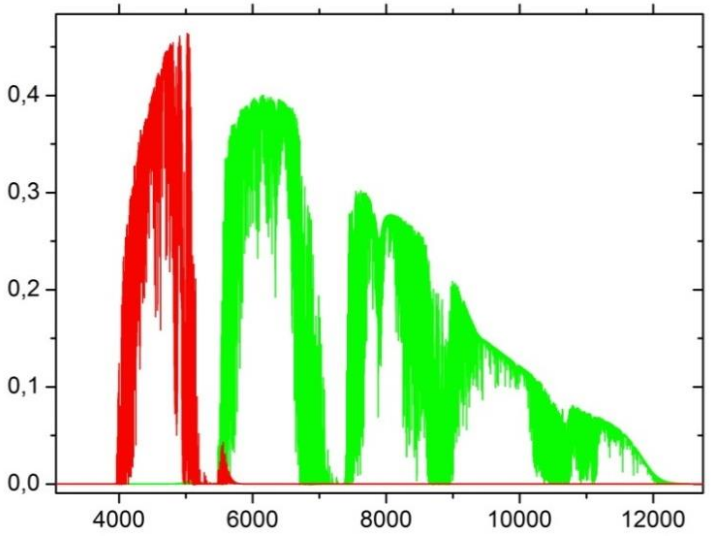

Outline

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  - Long Term Stability
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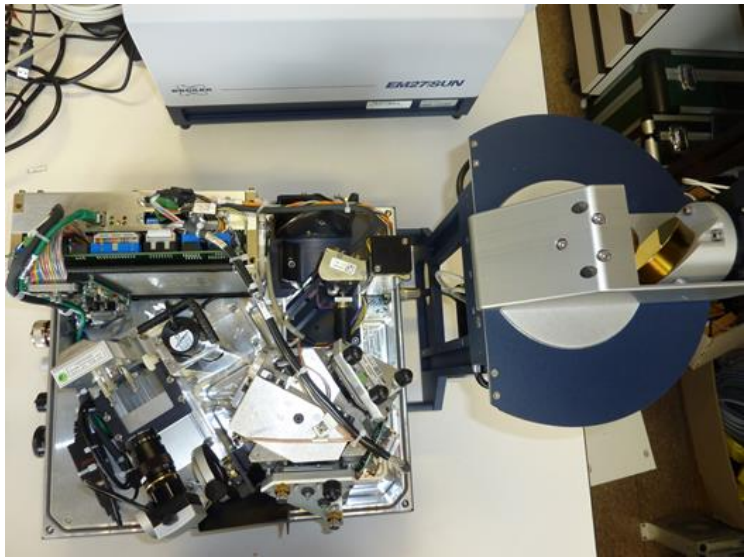
Introduction

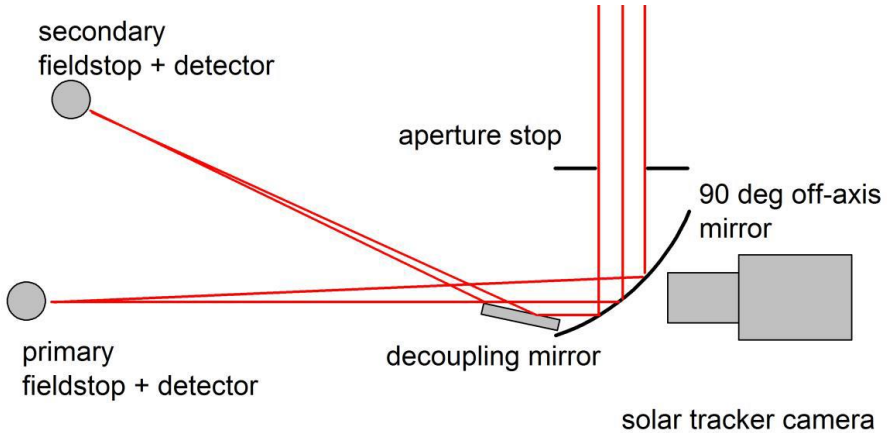
- Existing ground-based GHG networks
  - Validation of satelite measurements
  - NDACC: **N**etwork for the **D**etection of **A**tmospheric **C**omposition **C**hange
  - TCCON: **T**otal **C**arbon **C**olumn **N**etwork (Near-IR)
    - Geographic coverage limited, instruments not portable
    - Good infrastructure and expert maintenance required
- New upcoming ground-based GHG network
  - COCCON: **Co**llaborative **C**arbon **C**olumn **O**bserving **N**etwork
  - EM27/SUN spectrometer network
    - Portable and easy to set up instrument
    - High instrumental stability and reliability
    - Low-cost interferometer (100 k€)
    - Low infrastructure requirements

Fig. source: TCCON network

EM27/SUN – Instrument Overview

- Rock Solid^{TM} pendulum interferometer
  - 2 cube corners, CaF_2 beamsplitter
- Double sided interferograms
- Maximum OPD: 1.8 cm
- Resolution: 0.5 cm^{-1}
- Dimensions: 35 x 40 x 27 cm
- Mass with tracker: ~25 kg
- Tracker unit & SW developed at KIT
  - Gisi and Hase et al, AMT, 2012
- InGaAs detector
  - Spectral range: 5000 – 11000 cm^{-1}
- Second CO channel available
  - Spectral range: 4000 – 5500 cm^{-1}

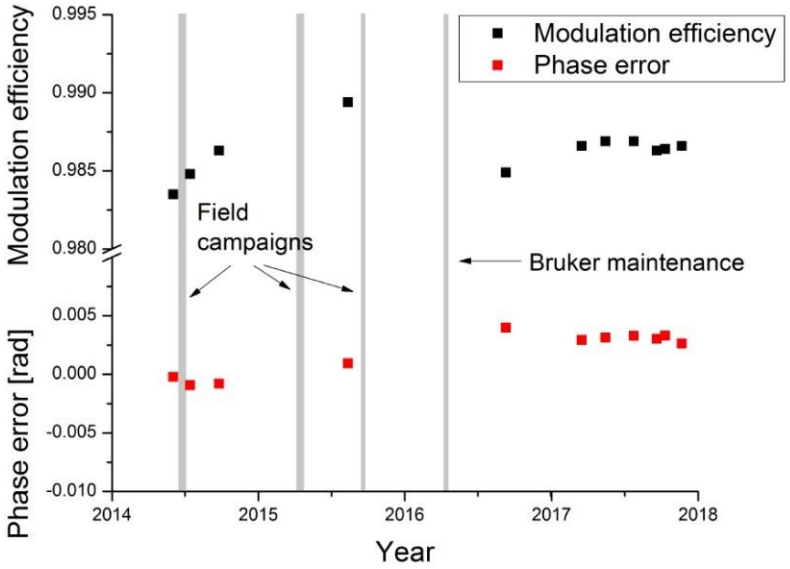




Hase et al, AMT, 2016

EM27/SUN – ILS and Stability

- Instrumental Line Shape (ILS)
  - Accurate ILS knowledge of highest importance
    - 1% ΔMEA at MOPD → 0.15% ΔXCO_2
  - Absorption lines of lab air water vapor
    - Externel source needed (50 W light bulb)
    - No gas cell necessary
- Long Term Stability (LTS)
  - Reference EM27/SUN spectrometer
  - Modulation Efficiency Amplitude (MEA)
    - 0.9862 ± 0.0015 → $\Delta XCO_2 < 0.03\%$
  - Phase Error
    - 0.0019 ± 0.0018

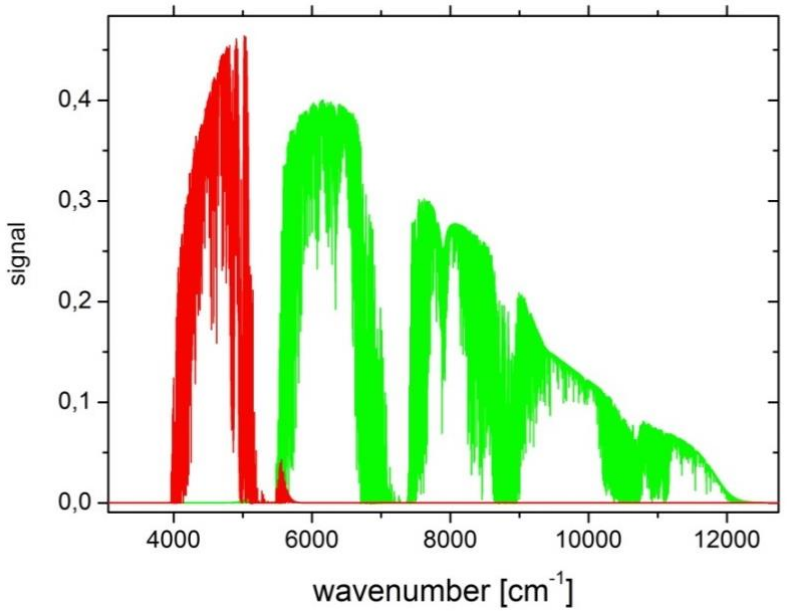


Frey et al, AMT (2015)

EM27/SUN – Calibration

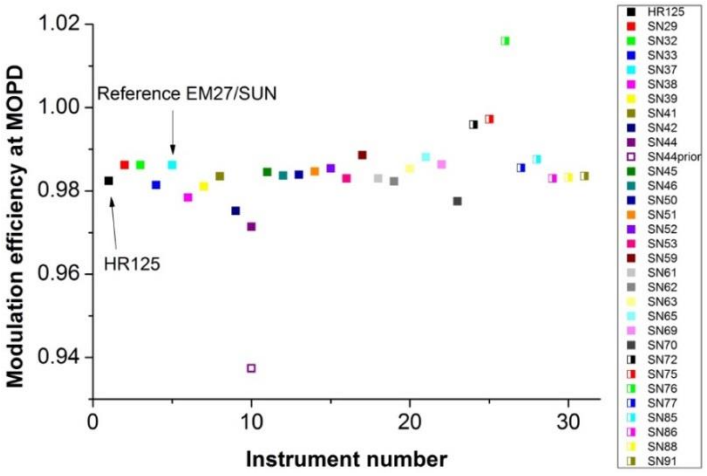
- Calibration measurements
  - Side-by-side calibration of instruments to common scale
  - Performed before and after several campaigns at IMK-ASF office building
- Additional pressure and temperature measurements
  - On site from tall tower at the KIT campus north
- More than 30 devices operated worldwide

IMK-ASF, KIT



COCCON – Service

- COCCON: **Co**llaborative **C**arbon **C**olumn **O**bserving **N**etwork
- Framework for EM27/SUN spectrometers
- Check of new instruments at KIT (before delivery to customer)
  - Solar measurements together with reference EM27/SUN and co-located TCCON instrument
  - Alignment check and ILS measurements
  - ILS ensemble mean: 0.985 $\pm$ 0.008
  - XCO_2, XCH_4, XH_2O and XCO scaling factors
- Loan of instruments possible for campaign deployment
- Retrieval algorithm available
  - PROFFIT and PROFFAST
  - Training at KIT possible
- Central facility for EM27/SUN spectra
  - Central processing facility
  - Central data handling facility
  - → COCCON-proceeds

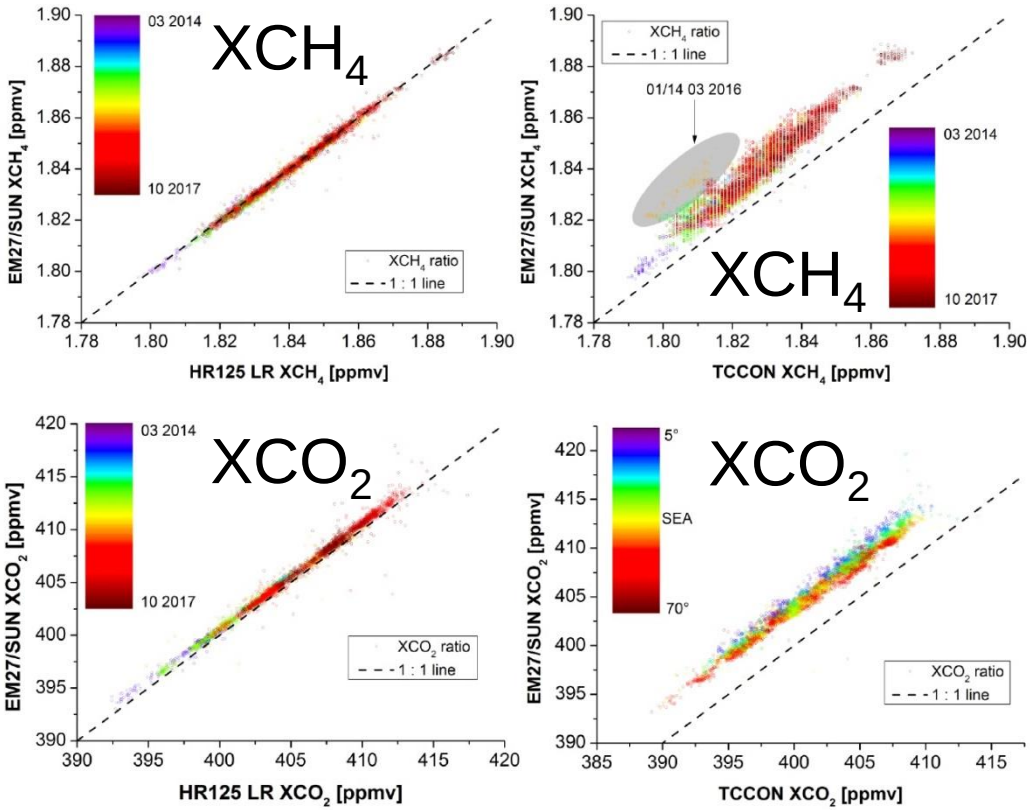


Frey et al, AMT (2019)

COCCON – Comparison to TCCON

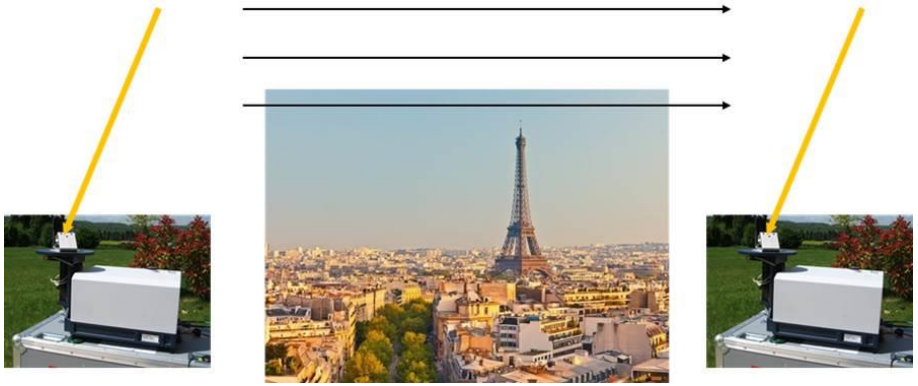
- High resolution spectrometer
  - Bruker IFS 125HR (KIT)
- Low resolution intercomparison
  - PROFFIT retrieval SW (same procedure for both data sets)
  - Excellent agreement
- Low versus high resolution
  - Different retrieval SW (PROFFIT vs. GFIT)
  - Different resolutions → Differing averaging kernels (0.5 cm^{-1} vs 0.02 cm^{-1})
  - Seasonal variability
  - No significant long term drift

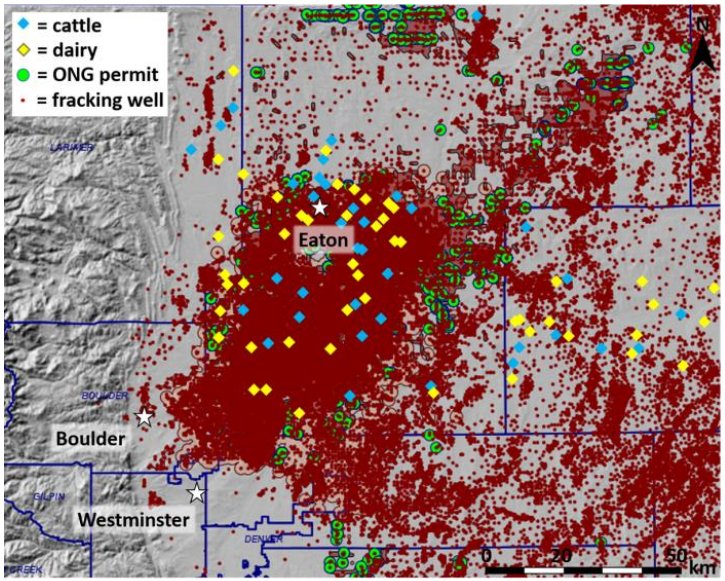
Frey et al, AMT (2019)



COCCON – Measurement Campaigns

- Measurement campaigns with partner institutions
  - Paris, Berlin, Boulder, Tokyo, etc.
  - City emissions, fracking, dairy farms, coal mining, etc
  - Poster Omaira Garcia
    - MEGEI-MAD Campaign
  - Talk Matthias Frey
    - Colorado Front Range Campaign



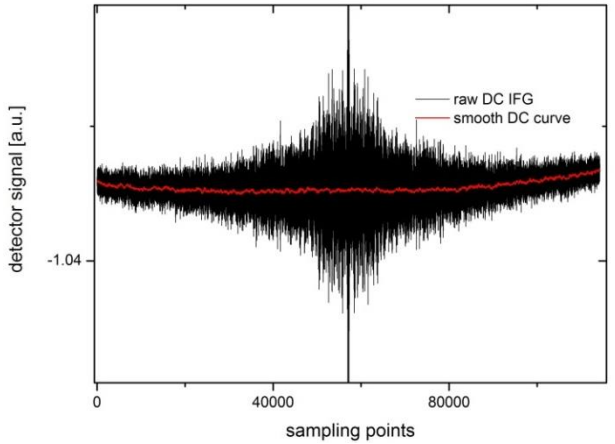


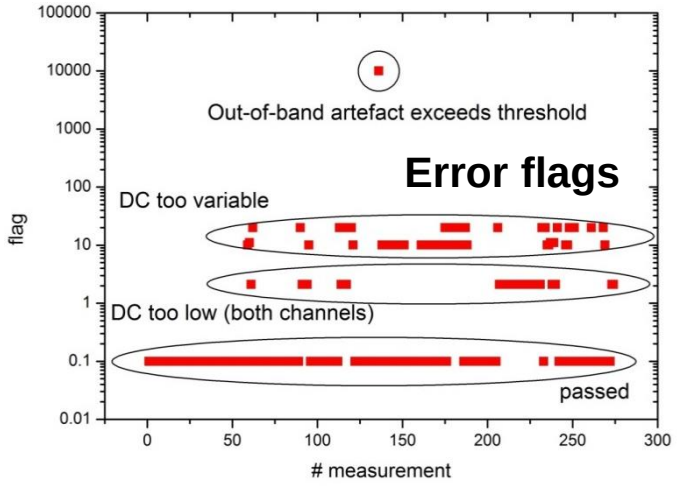
COCCON-Proceeds

- COCCON – Philosophy
  - Common standards for GHG measurements
    - Define and maintain an instrumental standard (EM27/SUN)
    - Verify performance of each device before delivery
    - Common way of data processing and analysis → COCCON-proceeds
- COCCON-Proceeds (project funded by ESA)
  - Pre-processing (by the user community member)
    - Measured IFG → Absorption spectra (binary files)
    - Quality checks (selection of good spectra)
  - Central processing and data handling facility
    - Upload pre-processed data
    - Analysis of absorption spectra
    - Data dissemination to user community

COCCON-Proceeds – Pre-processing

- Calculation of Solar position
- Read IFG (OPUS format), DC correction
- IFG truncation to nominal resolution
- Numerical apodization function
- Perform FFT, phase correction and resampling
- Quality checks
  - Minimum DC value to available ADC range
  - Maximum variability of DC in IFG
  - Centerburst amplitudes of FWD/BWD scans
  - Centerburst location in the IFG
  - Relative amplitudes of out-of band artefacts
  - Slope, curvature, and change of curvature of phase spectrum
  - Spectral calibration based on cross-correlation of spectral structure wrt a reference spectrum



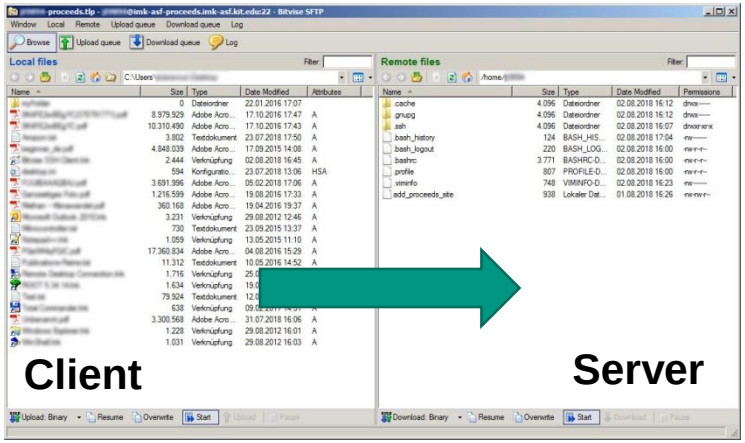


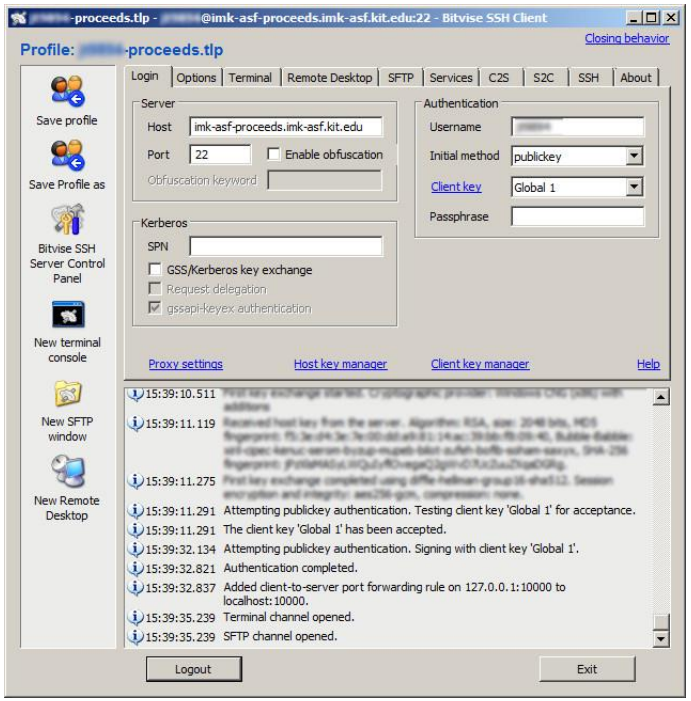
COCCON-Proceeds – Retrieval algorithm

- New retrieval algorithm PROFFAST designed for low resolution spectra
- Possibility to use TCCON map files as a priori profiles
- Internal postprocessing (airmass correction)
- 30 times faster than PROFFIT algorithm
- Software and code available via KIT website
- Preprocessing software and PROFFAST successfully used for the analysis of the MEGEI-MAD campaign measurements

COCCON-Proceeds – Central Facility

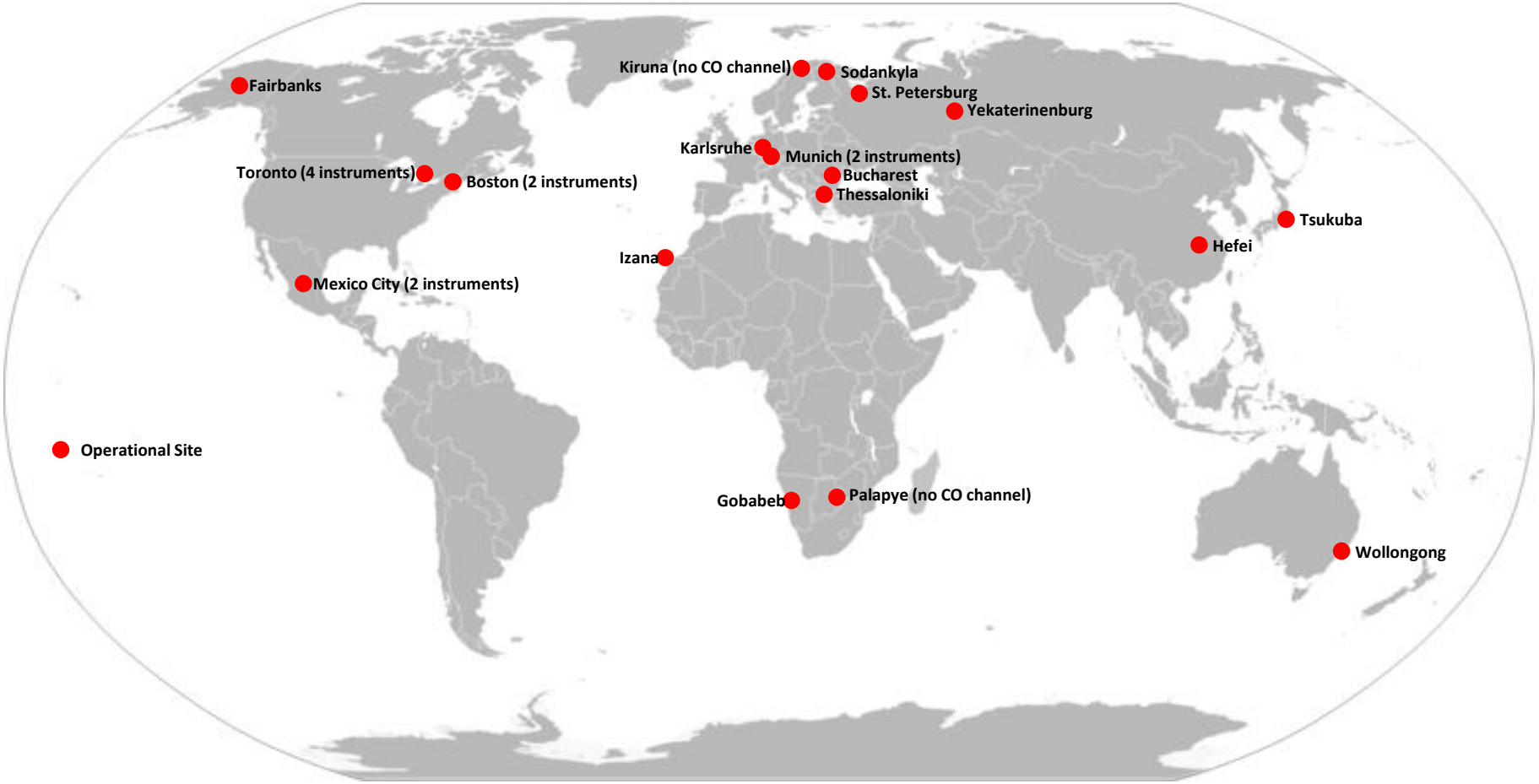
- Central processing and data handling facility
  - Upload pre-processed binary files
  - Analysis of absorption spectra
  - Data dissemination to the user community
- Interface for data upload
  - Linux server system
  - Secure File Transfer Protocol (SFTP)
  - Login interface (e.g. Bitvise for Windows) (username, phassphrase, etc.)





Login interface (Bitvise)

COCCON – Next Step



Summary and Outlook

- EM27/SUN spectrometer
  - ILS, LTS and Calibration
- COCCON
  - Service, Comparison to TCCON and Campaigns
- COCCON-Proceeds
  - Pre-processing with quality checks
  - Central processing and data handling facility

- SW-distribution to external users
  - Pre-processing tool and PROFFAST
  - Extension to all members

- Future plan: Global EM27/SUN data set

- Acknowledgement: the COCCON-Proceeds project was funded by the ESA