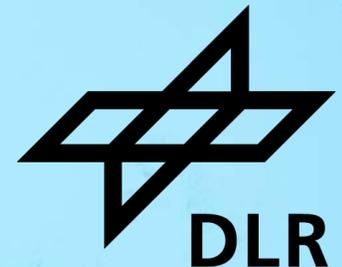


# **IMPLEMENTATION OF SI-TRACEABILITY IN THE TCCON AND COCCON OBSERVATIONS**

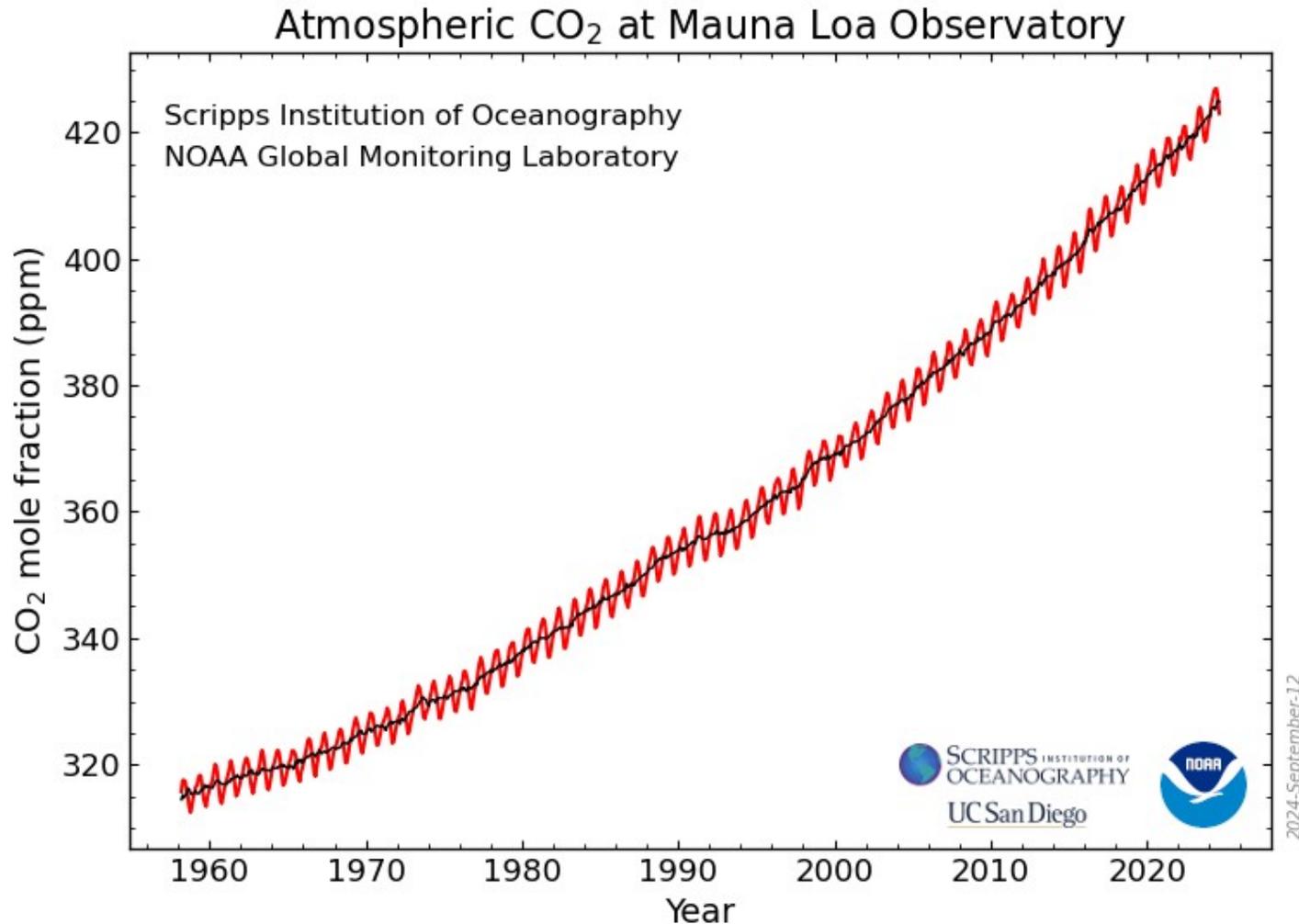
## **THE METROLOGY FOR COMPARABLE AND TRUSTWORTHY GREENHOUSE GAS REMOTE SENSING DATASETS (METCTG ) INITIATIVE**

**Dietrich G. Feist, Deutsches Zentrum für Luft- und Raumfahrt (DLR)**

**Manfred Birk (DLR), Andre Butz (U Heidelberg), Jia Chen (TUM), Marc Coleman (NPL),  
Tom Gardiner (NPL), Frank Hase (KIT), Rigel Kivi (FMI), Gang Li (PTB), Christian  
Monte (PTB), and Rainer Stosch (PTB)**



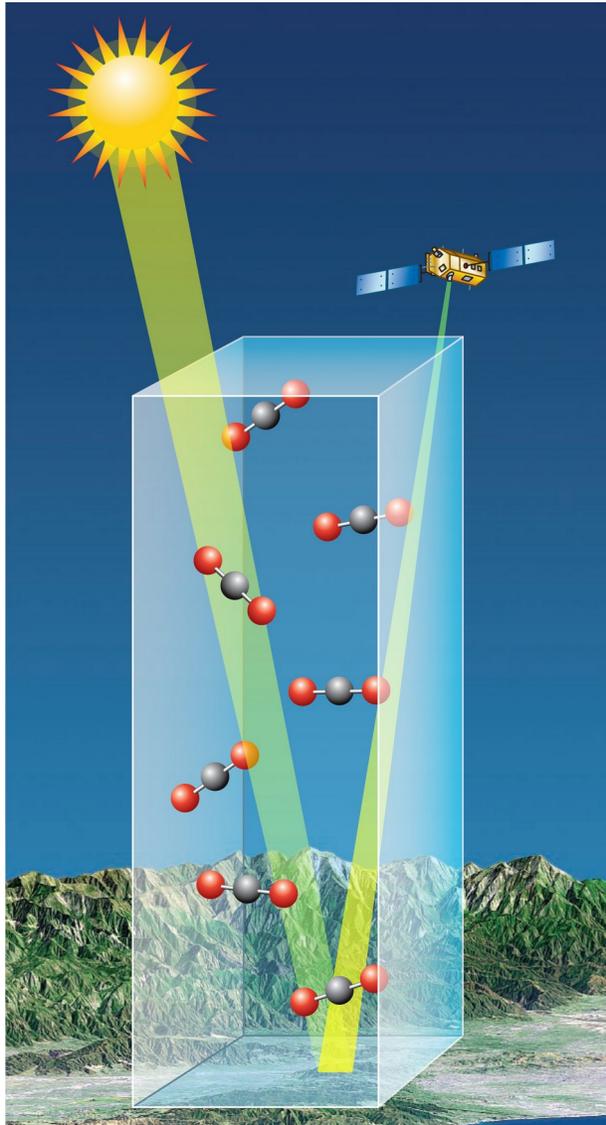
# In-situ observations of atmospheric greenhouse gases



- Long-term record for CO<sub>2</sub>, CH<sub>4</sub> and other trace gases
- Ground stations, towers, ships aircraft
- Measurements calibrated against WMO/GAW GHG scales (cylinders with well-defined reference gas mixtures)
- SI traceability established for WMO/GAW GHG scales

<https://www.esrl.noaa.gov/gmd/ccgg/trends/>

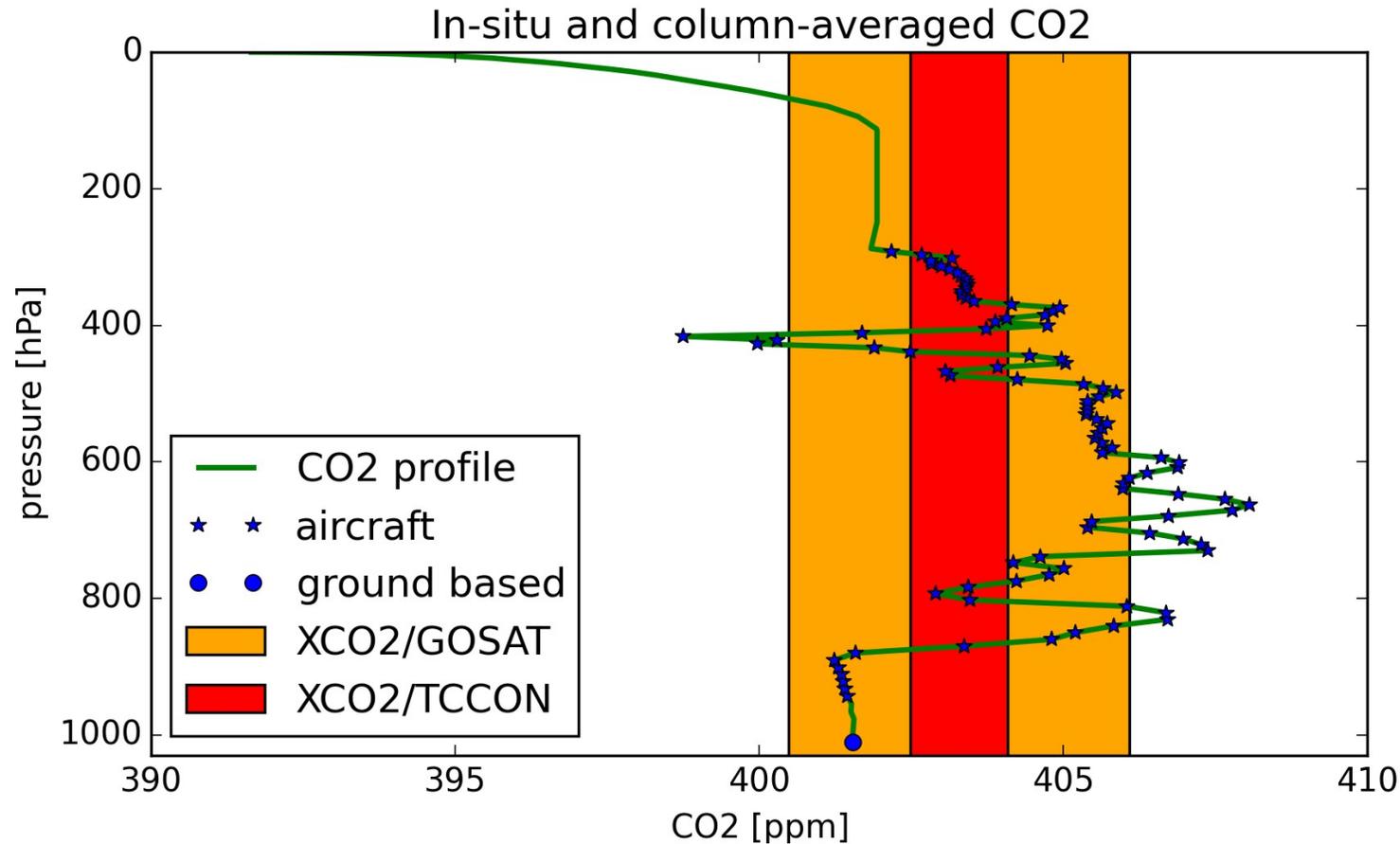
# Remote sensing of atmospheric greenhouse gases



<http://oco.jpl.nasa.gov/>

- For remote sensing, measure absorption by GHGs in atmospheric solar spectra
- Application from satellite instruments as well as ground-based stations
- Derive total columns of CO<sub>2</sub>, CH<sub>4</sub> and O<sub>2</sub>
- Use O<sub>2</sub> column as proxy for airmass
- Observed quantity is column-averaged dry-air mole fraction  $X_{CO_2}$  for CO<sub>2</sub>, and  $X_{CH_4}$  for CH<sub>4</sub>.
- All current satellite GHG missions with global coverage use this approach.

# Relation between in-situ and column-averaged observations

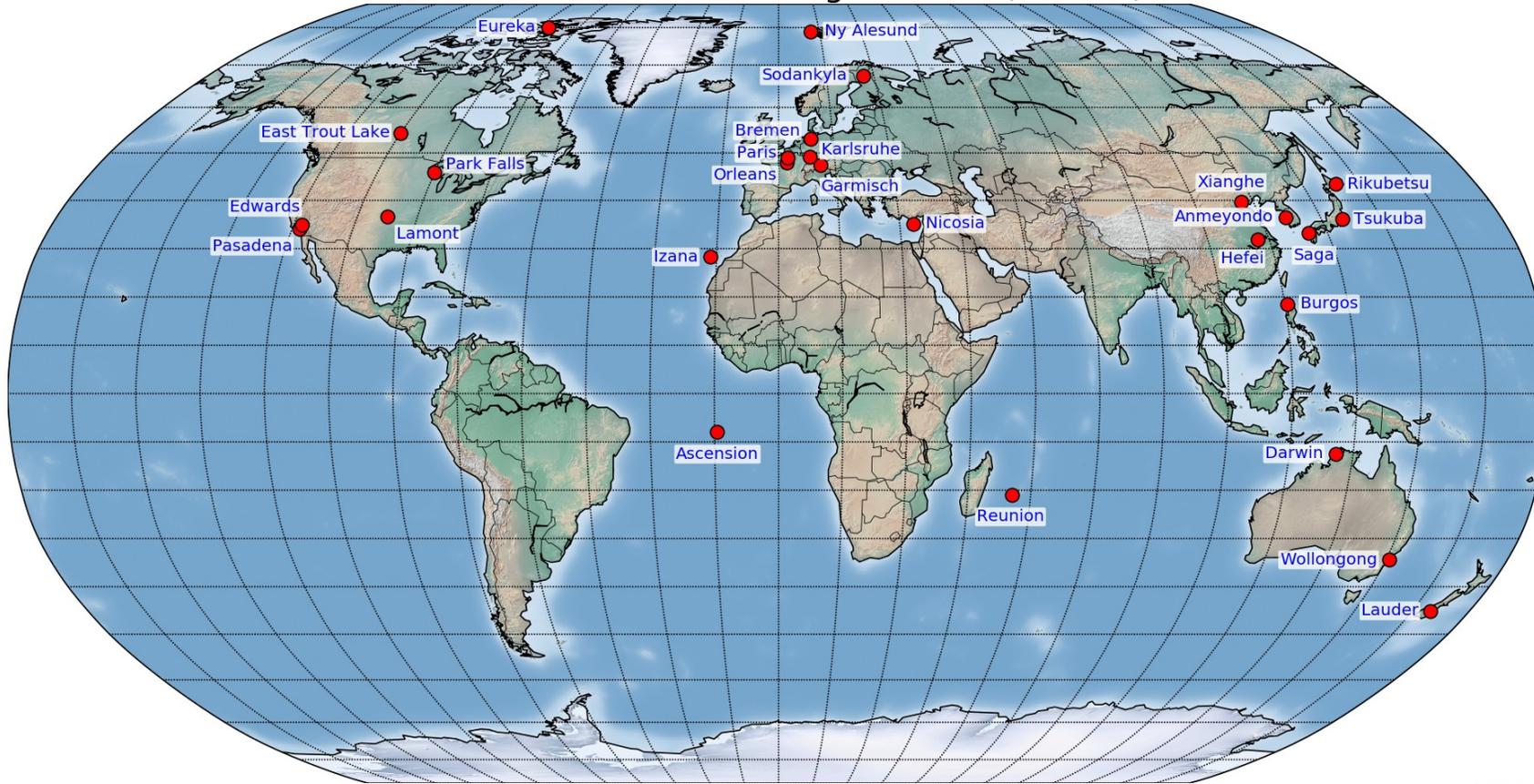


- Altitude coverage of in-situ measurements depends on platform
- Column-averaged observations provide single value representative of (part) of the atmospheric column
- Both quantities cannot be compared directly

# Total Carbon Column Network (TCCON)



Total Carbon Column Observing Network (TCCON) 2022

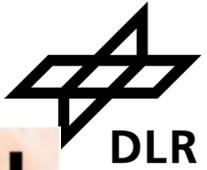


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- Network of ground based FTIR stations
- Different groups, common standards
- High-precision column observations of CO<sub>2</sub>, CH<sub>4</sub>, CO, N<sub>2</sub>O.
- Crucial reference for satellite GHG measurements

# Collaborative Carbon Column Network (COCCON)



## Portable spectrometers for GHG observations

KIT started in 2011 the development of a novel compact NIR-FTIR spectrometer for carbon cycle research, in cooperation with Bruker Optik GmbH. Result was the Bruker EM27/SUN.



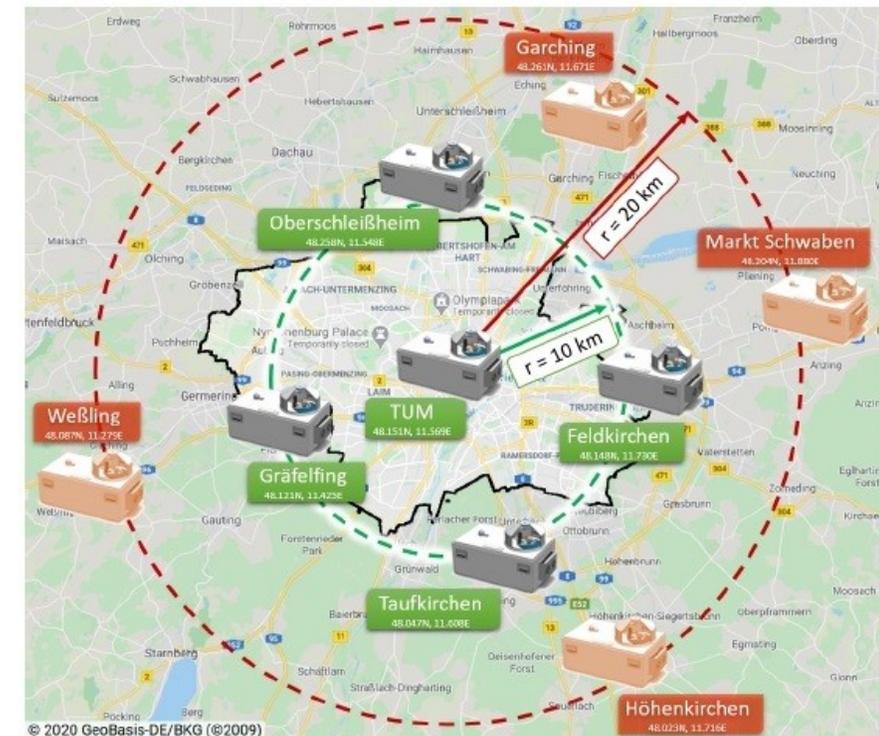
Gisi, M., Hase, F., Dohe, S., Blumenstock, T., Simon, A., and Keens, A.: XCO<sub>2</sub>-measurements with a tabletop FTS using solar absorption spectroscopy, Atmos. Meas. Tech., 5, 2969–2980, 2012.



Many applications due to the smaller size and lower investment:

- campaigns
- local networks (e.g. Munich)
- long-term observations
- traveling standard

Dietrich, F., **Chen, J.**, Voggenreiter, B., Aigner, P., Nachtigall, N., and Reger, B.: MUCCnet: Munich Urban Carbon Column network, Atmos. Meas. Tech., 14, 1111–1126, <https://doi.org/10.5194/amt-14-1111-2021>, 2021.



# Traceability chain for TCCON and COCCON



*WMO/GAW manometric standard*

SI

WMO/GAW GHG scale

TCCON in-situ scale

TCCON instrument

TCCON instrument

**KIT TCCON instrument**

TCCON instrument



*TCCON aircraft calibration*



*KIT TCCON instrument*

COCCON instrument

COCCON instrument

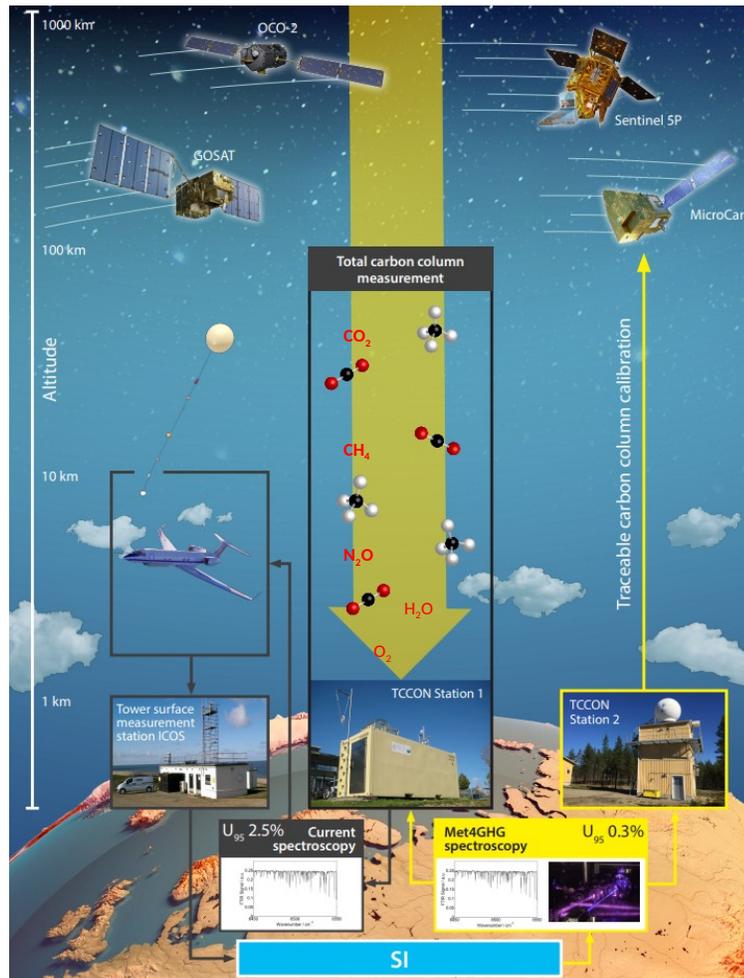
**COCCON reference instrument**

COCCON instrument



*COCCON reference calibration*

# Traceable spectroscopic parameters for column-averaged greenhouse gas observations



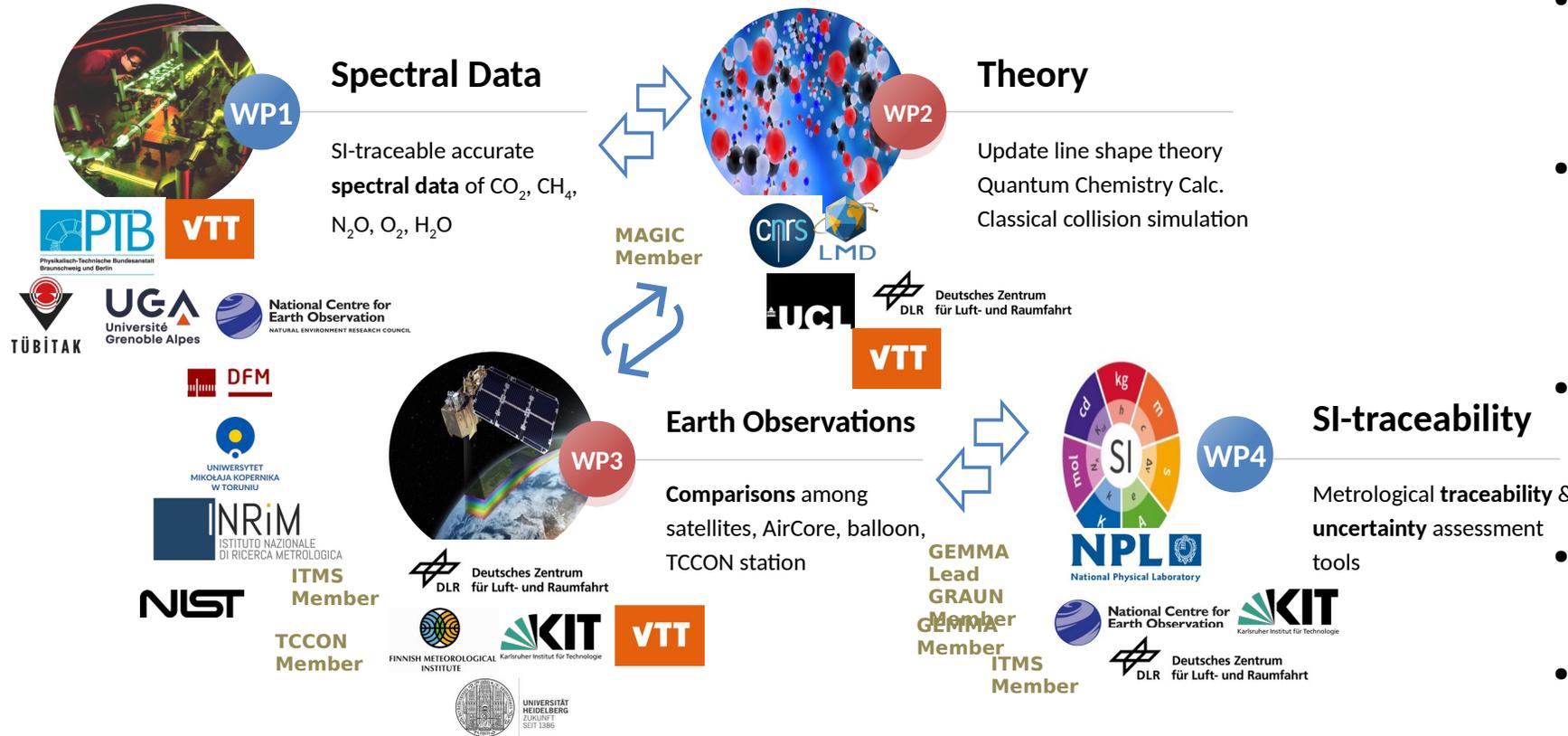
- Spectroscopic parameters used in Xgas retrievals for TCCON and COCCON are not traceable to SI
- Bias in spectroscopic parameters causes a scaling bias between the intrinsic TCCON scale and the WMO/GAW in-situ scale
- TCCON Xgas results are scaled by a network-wide factor derived from aircraft and balloon in-situ measurements over TCCON sites
- SI traceable spectroscopic parameters (and retrieval codes) could provide a new traceability chain for remote sensing GHG observations.

# The Metrology for Comparable and Trustworthy Greenhouse gas remote sensing datasets (MetCTG) initiative



## Objectives

- SI-traceable accurate spectral data of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, O<sub>2</sub>, H<sub>2</sub>O
- Metrological validation assisted by quantum chemistry calculation & classical simulation
- Field comparisons among satellites, AirCore, balloon, TCCON station
- Metrological traceability & uncertainty assessment tools
- Impact to Databases: HITRAN, GEISA; Agencies: WMO, ESA, NASA; GCOS/WMO networks: GRUAN and TCCON; Policy making



# Conclusions



- TCCON and COCCON provide the calibration reference for most current and planned satellite GHG missions.
- TCCON is calibrated and traceable to the WMO/GAW in-situ GHG scales.
- This calibration is achieved through many aircraft and balloon profiles measured by in-situ instruments over several TCCON stations.
- COCCON is calibrated and traceable to the TCCON scale.
- With traceable spectroscopic parameters, a new traceability chain for GHG remote sensing could be established.
- The MetCTG initiative aims at solving several of the open issues of traceable spectroscopy. A Joint Research Proposal will be submitted in response to the European Partnership on Metrology Call 2024.