A New NDACC- and TCCON-Compliant FTIR Observatory in Bologna (Italy) for Greenhouse Gas and Trace Gas Measurements

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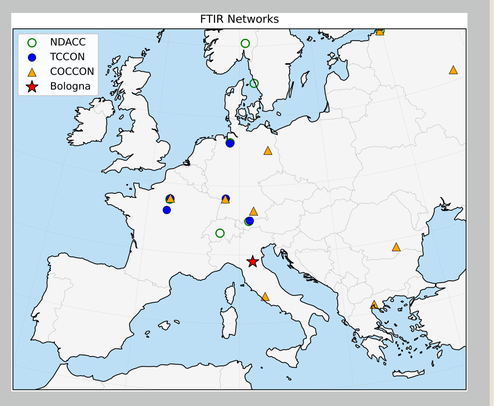
Introduction

High-resolution ground-based Fourier Transform InfraRed (FTIR) spectroscopy is a key technique for monitoring atmospheric composition, particularly greenhouse gases, providing vertically integrated information essential for climate studies, emission estimates, and satellite validation. Within the framework of the PNRR EMM and ITINERIS projects, two ground-based FTIR spectrometers have been installed at the CNR research area in Bologna, strengthening national observational capabilities in this field.

The FTIR spectrometers are located in the Po Valley, one of the most polluted regions in Europe, offering a unique opportunity to observe greenhouse gases and air pollutants under conditions of strong anthropogenic influence.



EM27/SUN

The second instrument is a Bruker EM27/SUN, which operates in the NIR range from 4 000 to 12 000 cm^{-1}, thus allowing the retrieval of CO_2, CH_4, CO, and H_2O. Being part of the COCCON network, its data are analyzed on a daily basis, and the resulting GEOMS files are regularly delivered to the network for public distribution.





Figure 1: Bruker EM27/SUN.

Results

Time Series

- XCO_2: seasonal cycle + increasing trend (Apr 24–26)
- XCO: summer spikes from North America wildfire plumes → intrusions over Europe/Po Valley
- XCH_4: winter max, summer min
- XH_2O: strong seasonal variability

TROPOMI Comparison

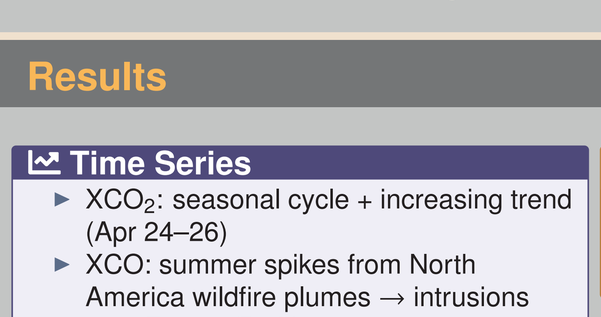
- $\Delta t = 15$ min, $r = 20$ km.
- Same spectral region
- Bias: CO −0.28%, XCH_4 −0.13%
- Agreement on wildfire CO events
- XCH_4 underestimation in some days (ongoing analysis)

Quality Control

- XAIR detects instrumental drifts and clouds affecting spectra
- Filter: $|XAIR-1| > 2\%$

Single-Day Variability

- XCO_2, XCH_4: PROFFAST calculates values from both detectors
- High temporal resolution: ~1 min → ~5 ppm drop in XCH_4 at 12:20, 14:00, and 15:00
- Linked changes in XH_2O, weaker in XCO_2 (possible clean air intrusion)



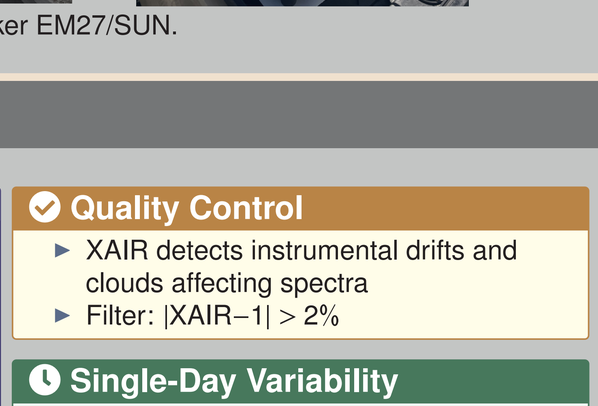
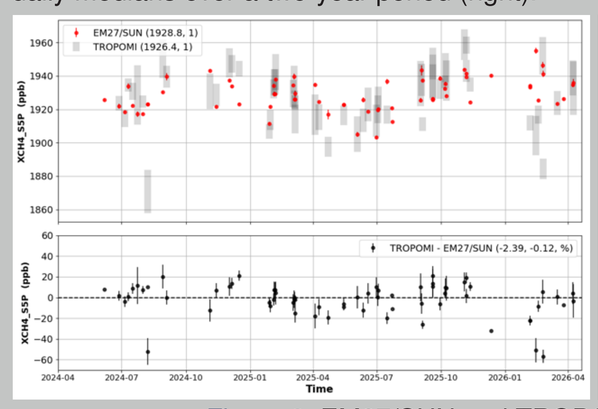


Figure 2: EM27/SUN mole fraction columns of selected species: one-day measurements (left) and daily medians over a two-year period (right).



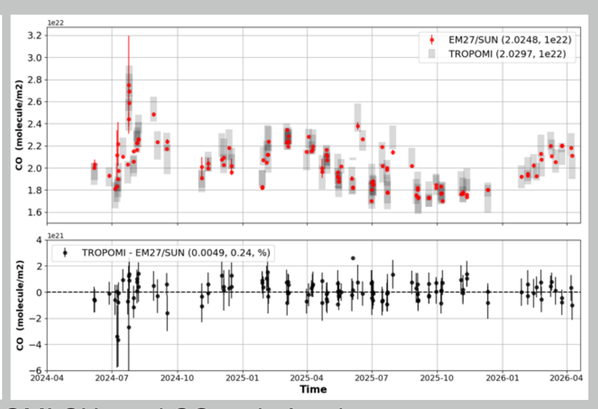


Figure 3: EM27/SUN and TROPOMI CH_4 and CO mole fractions.

IFS 125HR

The first instrument, a Bruker IFS 125HR, operates in the infrared spectral range from approximately 700 to 13 000 cm^{-1}, with a spectral resolution of about 0.0036 cm^{-1}, enabling the retrieval of a wide set of atmospheric trace gases and minor atmospheric constituents, including CO_2, CH_4, N_2O, CO, O_3, HNO_3, HCl, HF, C_2H_6, HCN, and HDO. These measurements are crucial for investigating changes in atmospheric composition and their impact on the Earth's radiative balance, as well as for deriving greenhouse gas emissions and trends. It is fully compliant with NDACC and TCCON network requirements.





Figure 4: Bruker IFS125HR in operation. Right: zoom on the solar input.

Instrument characteristics

Parameter	IFS 125HR	EM27/SUN
Spectral range	0.7–13k cm^{-1} (14.3–0.77 μm)	4–12k cm^{-1} (2.5–0.83 μm)
Spectral resolution	0.0036 cm^{-1}	0.5 cm^{-1}
Measurement type	High-resolution FTIR	Portable low-resolution FTIR
Optics	Gold-coated MIR optimized	Compact sealed optics
Detectors	MCT, InSb, InGaAs	InGaAs
Cooling	Liquid N_2 (MCT, InSb)	No cryogenic cooling
Beamsplitters	KBr, CaF_2	CaF_2
Spectral channels	Dual-channel capability	Dual channel
Sun tracker	External automated system	Integrated solar tracker
Portability	Laboratory-based	Portable, field deployable
Vacuum system	Yes (0.025 hPa)	No vacuum (sealed system)
Light sources	NIR, MIR internal sources	Solar only
Filter wheels	Yes (3 wheels)	No
Typical applications	Trace gases, vertical profiling	Column GHG monitoring
Networks	NDACC / TCCON	COCCON / TCCON

Operative measurements (TCCON standards)

The comparison between IFS 125HR (0.02 cm^{-1}) and EM27/SUN (0.5 cm^{-1}) spectra highlights clear resolution-dependent effects in regions with narrow absorption features. In the 4520–4560 cm^{-1} interval, lines are well resolved in the IFS 125HR but appear broadened and blended in EM27/SUN, consistent with dense and sharp CH_4 transitions dominating this band.

In contrast, the 6310–6370 cm^{-1} region shows minimal differences between the instruments. The spectra are largely consistent, indicating broader absorption features, primarily due to CO_2, and thus a weaker sensitivity to spectral resolution. These results confirm that resolution effects are most pronounced in regions dominated by narrow molecular lines.

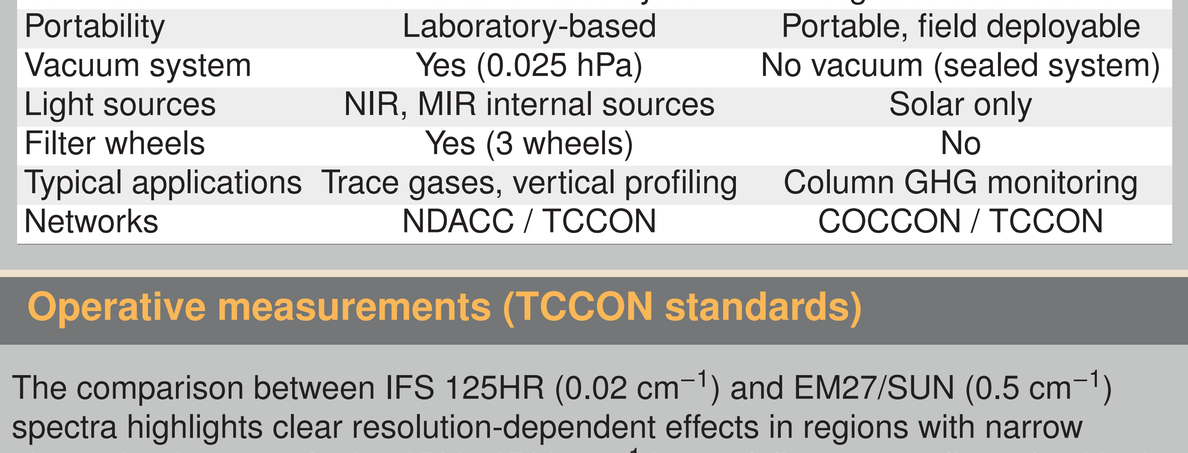


Figure 5: IFS125HR and EM27/SUN spectra comparison.

Conclusions

Recently, two FTIR instruments have been installed and are now fully operational at the ISAC-CNR facility in Bologna. Being compliant with network standards, they ensure standardized procedures for data acquisition, calibration, and processing, enabling consistent and comparable measurements across different ground-based FTIR stations worldwide, as well as reliable intercomparisons with satellite observations. This installation represents the first FTIR facility of its kind in Italy and in the central Mediterranean region, providing substantial scientific value at both national and international levels.