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# Harwell TCCON Observatory for GHG atmospheric columns

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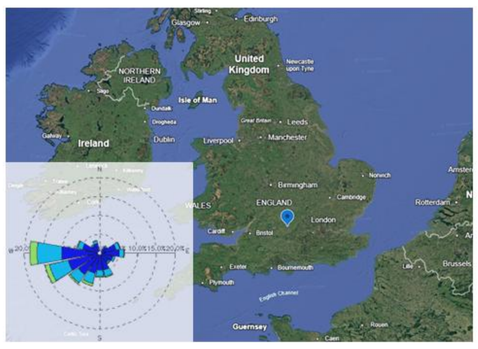
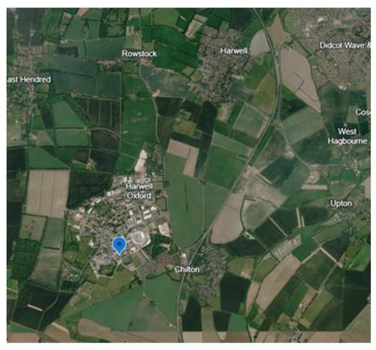
## Introduction – site description and uniqueness

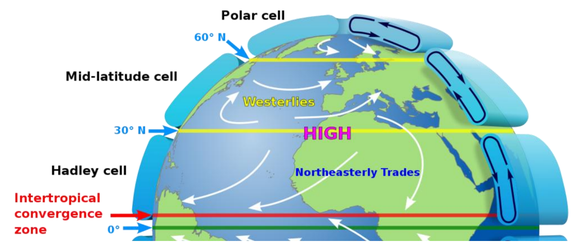



**Above**: Site location within the British Isles (left) and in the immediate region (right). **Inset**: Prevailing diurnal winds (09/2020 – 06/2026) correspond to global circulation (right bottom) Westerlies, i.e., tropical and polar maritime air masses.

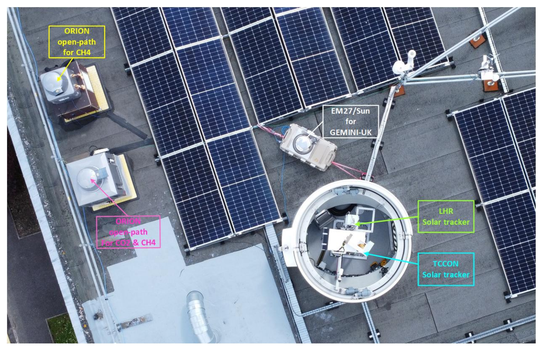
**The Harwell TCCON observatory**

- Located in Harwell Campus, 6 km SW of Didcot, Oxfordshire
- Rural location – Agricultural local GHG sources
- Established in September 2020, accredited Sept 2021
- Dataset covering 5 years – available from 2 databases
- > 12h consecutive measurements during clear peak summer days
- **Unique location : capture large-scale atmospheric exchanges between the Atlantic and continental Europe**
- **No large European city GHG sources upstream**




Data used for :

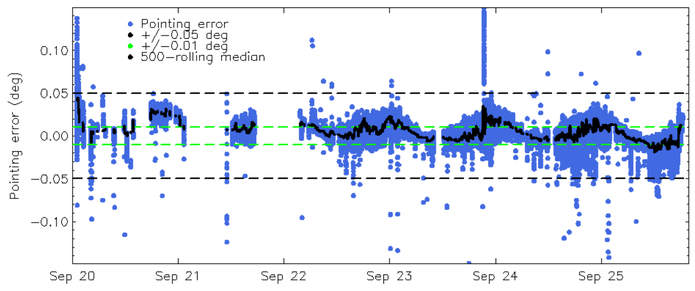
- **satellite Cal/Val** activities (S5P, OCO3, GOSAT, TANSAT, ...)
- **Global emission monitoring** (e.g. Canadian biomass fires)
- **Regional / national GHGs emission** monitoring (e.g. UK GEMMA)
- Carbon cycle studies




**The rooftop laboratory around TCCON station**

- Starting expanding in May 2023
- See right for instruments
  **+ MAXDOAS** (not included in picture)
- Includes a **EM27/SUN from UoLeicester** to link the UK GEMMA GHG emission monitoring network to TCCON

## Instrumental quality




**Pointing**

Assessed using frequency of $O_2$ solar & telluric lines.

**In-house** tracker system performs well.

Noticeable seasonal pattern.

Likely related to solar intensity.

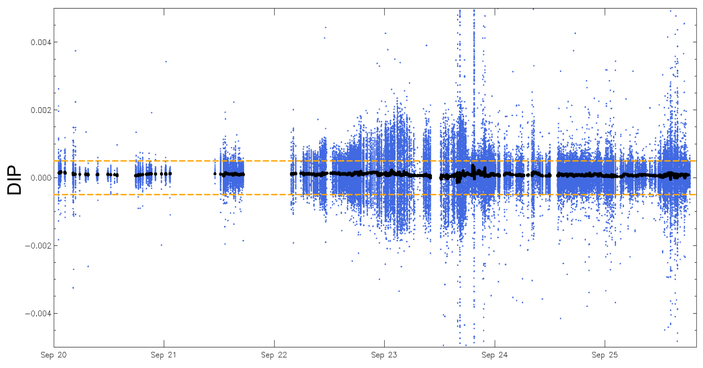
**Non linearity - Dip**

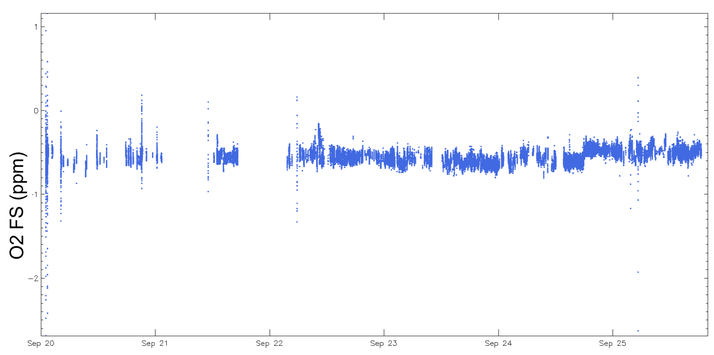
InGaAs detector leans towards supra-linearity.

Not significant to need correction.

Large outliers (e.g., August 2024) linked to vibrations on site.

Small outliers due to electrical noise pick up.




**System performance**

Assessed through $O_2$ Frequency Shift (FS).

Represents system degradation, misalignment etc.

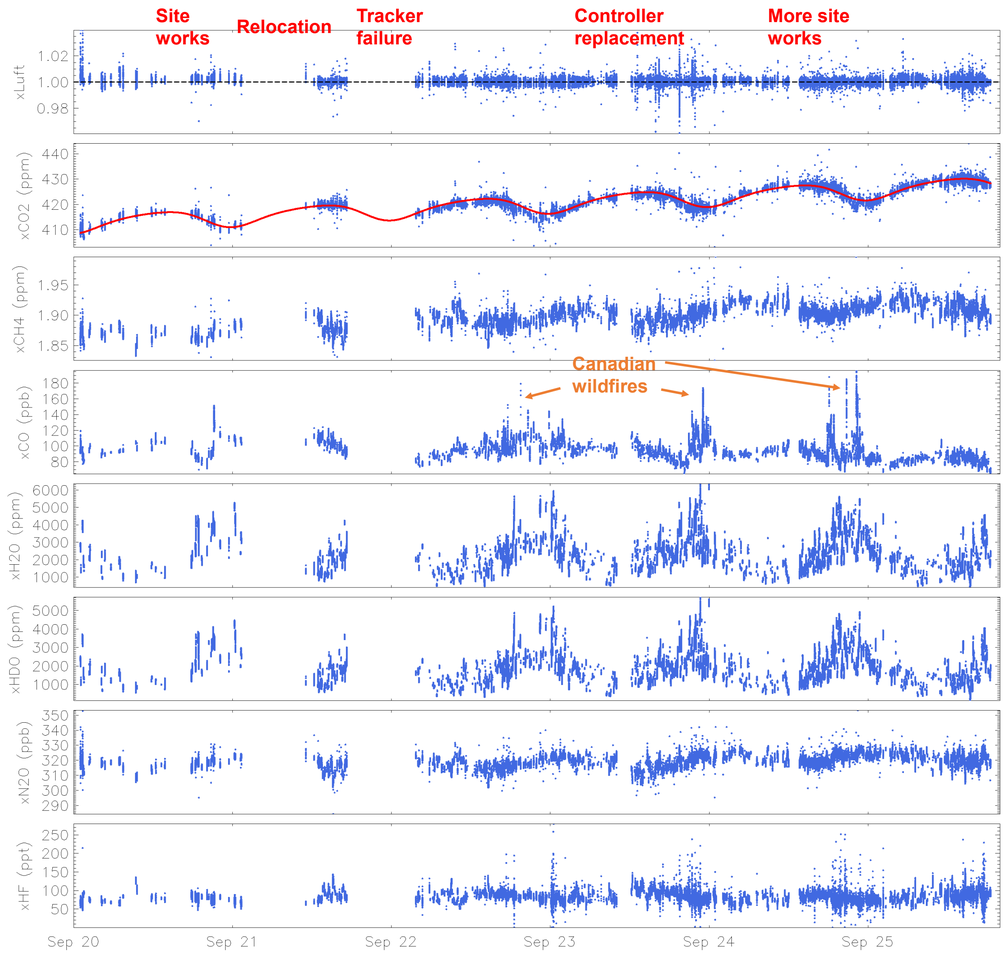
Internal IFS pressure sensor was found to be not good enough.

Change in August 2025 to high accuracy P sensor.

Impact of dirty optics.

## Data record and quality

### Temporal evolution of column-averaged dry VMRs




Main error sources in gas VMRs:

1. **Spectroscopic errors:** Tackled by using Airmass Dependent Correction Factors, derived by *in situ* measurements.
2. **Reference column:** Columns are tied to the WMO scale. Moreover, they are normalised by the column of dry air, retrieved from the $O_2$ band, avoiding $H_2O$ interference and surface pressure effects.
3. **Line shape:** See *Instrumental quality* on the left.
4. **Solar tracker pointing:** See *Instrumental quality* on the left.

Almost 5 full season cycles, with most prominent for:

$X_{CO2}$: fitted with Lindqvist model

$X_{CO}$ : notable by the Canadian boreal fires

$X_{H2O}$: the consistently-delayed always-humid British summer

**xLuft represents the retrieval of the dry-air column. Only measurements which passed QA/QC shown.

More on Canadian fires!

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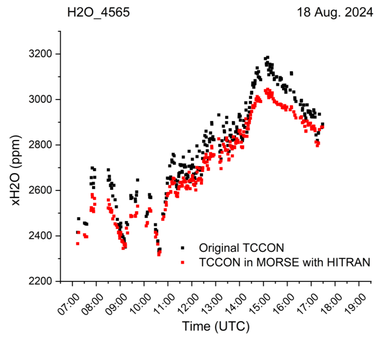
**The Harwell facility is a standard OCO-2 validation target since May 2022.**

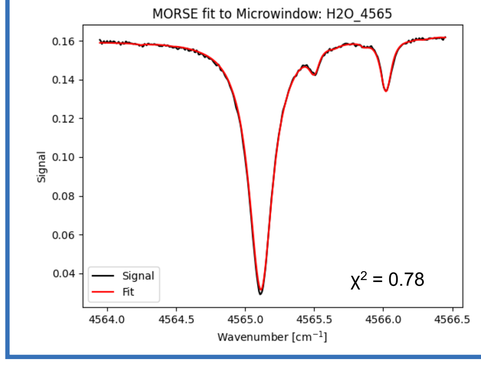
## Optimum Estimation retrieval algorithm in dev.

**MORSE** (Multispectral Orbital Retrieval using Sequential Estimation)

- Sequential OEM : Iterative ingestion of uncorrelated measurements
- Originally for satellite data retrievals (Limb and nadir sounding)
- Adaptation to **ground-based direct solar measurements**
- **First preliminary results on a TCCON micro-window**
- Collaboration with A. Dudhia (Uni. Of Oxford - author of the algorithm)

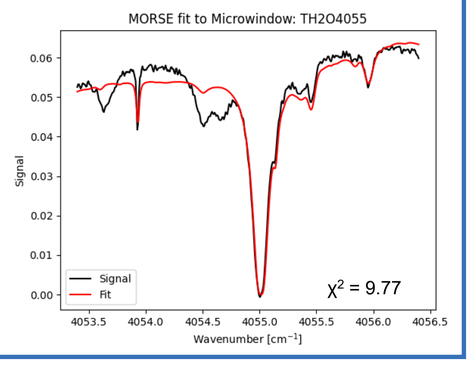
- MORSE underestimates $H_2O$: -68 ppm mean bias
- $O_2$ air mass correction not yet implemented
- Currently developing the ingestion of TCCON linelists



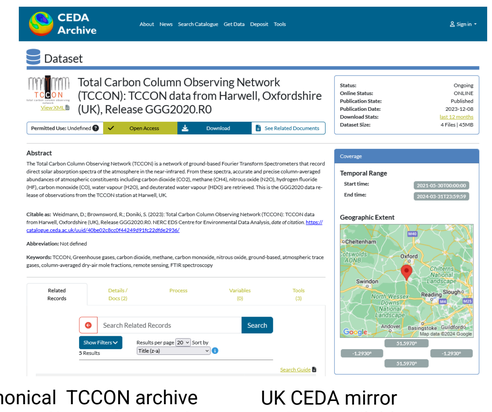




MORSE fit to TCCON $H_2O$ window that fits well using only HITRAN2020 linelist.

However, most of the time the HITRAN linelist is inadequate for NIR.




## Data availability and usage




Canonical TCCON archive

- **https://tccondata.org/**
- First batch in Autumn 2021
- **338 unique views**
- **54 unique downloads**

UK CEDA mirror

- First available Dec. 2023
- Available via **JASMIN**
- **Accessed 2233 times**
- **Downloaded 1006 times**

**Check the data on CEDA!**

## Perspective

- Continuation of operation and delivery of high-quality data
- EoI to participate to CO2M validation
- Interest in participating in S5 validation
- Planning a verification against a calibrated KIT EM27/SUN
- Continuing development of MORSE retrieval for wider comparison to GGG
- Option to process EM27/SUN data with MORSE
- Developing traceability of UK GEMINI network of EM27/SUN to TCCON
- Harwell UK acting as a test site for novel GHG sensing systems

## Recent relevant papers

**Vo**shtani et al., 2025, https://doi.org/10.5194/acp-25-15527-2025

Kurganskiy et al., 2025, https://doi.org/10.5194/amt-18-7525-2025

Schneising et al., 2025, https://doi.org/10.5194/egusphere-2025-5422

Bharathan et al., 2026, https://doi.org/10.5194/egusphere-2026-1029

Keya et al., 2026, https://doi.org/10.5194/egusphere-2026-1034

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Anu Dudhia (University of Oxford)