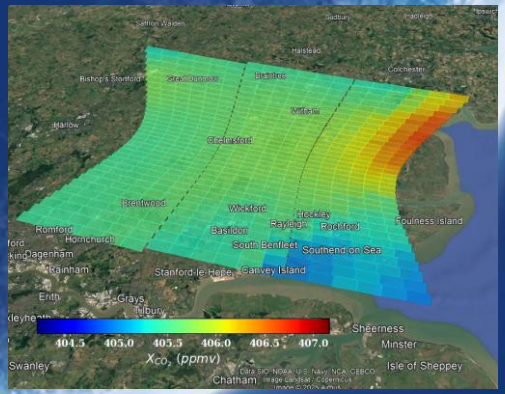
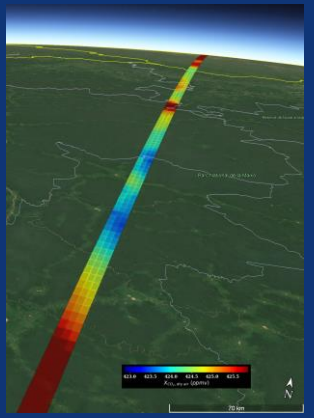
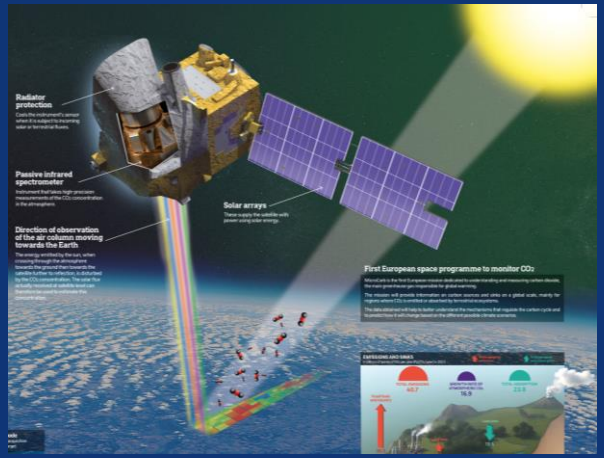




MicroCarb status after launch and needs towards the COCCON community

COCCON telecon 02/10/2025



Denis JOUGLET
(MicroCarb performance manager, CNES)
denis.jouglet@cnes.fr

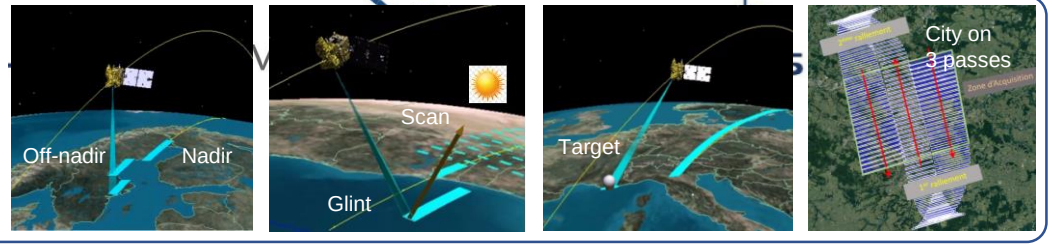
Christel GUY
(MicroCarb validation means manager, CNES)
christel.guy@cnes.fr

MicroCarb at a glance

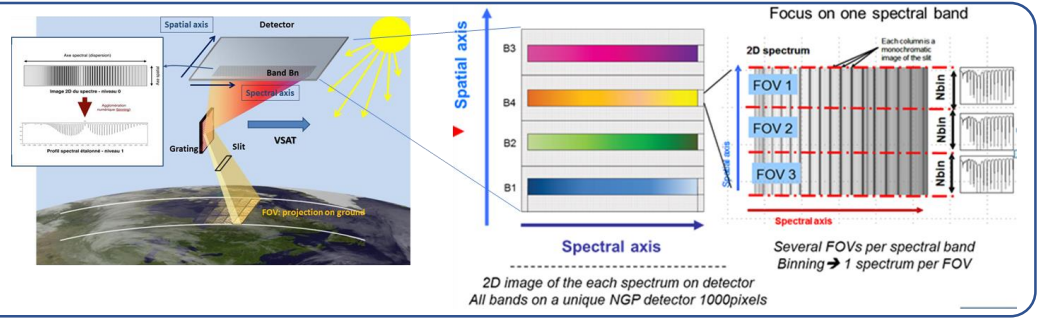
- **Main product: CO_2 column integrated concentration**
  - Rqmt for random error < 0.5 ppm (G) , < 1.5ppm (T)
  - Rqmt for regional bias < 0.1 ppm (G), < 0.2 ppm (T)
- **Objectives**
  - Natural CO_2 fluxes at regional scale
  - Demonstrator for CO_2 anthropogenic emissions (city mode)
- **Orbit**
  - Polar sun-synchronous, alt 649 km, descending node 10h30
  - Cycle 25 days, sub-cycle 7 days, ± 200km ACT mirror

  ➔ Any target can be observed once a week
- **Observations modes**
  - Science: Nadir, scan, glint, city
  - Calibration: Shutter, Lamp, Sun, Moon, Limb
  - Validation: Fixed-Target, Off-nadir target
- **Instrument**
  - Passive SWIR grating spectrometer
    - O_2 0.76 µm, O_2 1.27 µm, CO_2 1.61 µm, CO_2 2.05 µm
    - High resolving power (λ/FWHM = 25,000)
    - 3 ACT footprints 4.5x9 km²
  - Embedded imager (red band, 140m) for cloud & geolocation
  - Compact instrument (80 kg, 60W) on micro-satellite (180kg)
- **XCO2 retrieval : 4ARTIC**
  - Full physics model, retrieval by optimal estimation

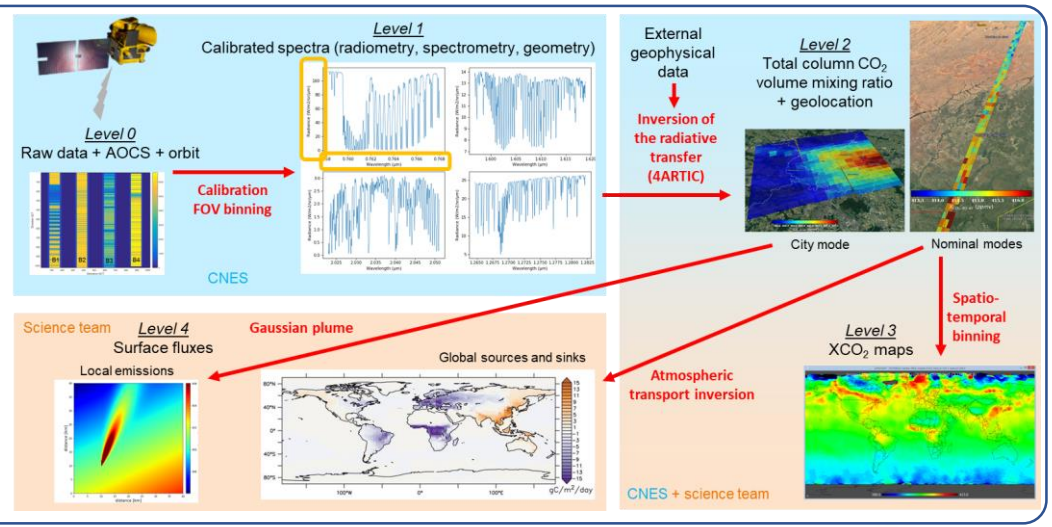
MODES



MEASUREMENTS

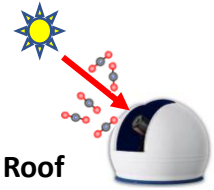


PRODUCTS



MicroCarb TVAC atmospheric observations (fall 2022)

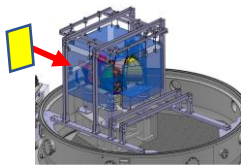
Solar test setup during TVAC



Roof heliostat telescope

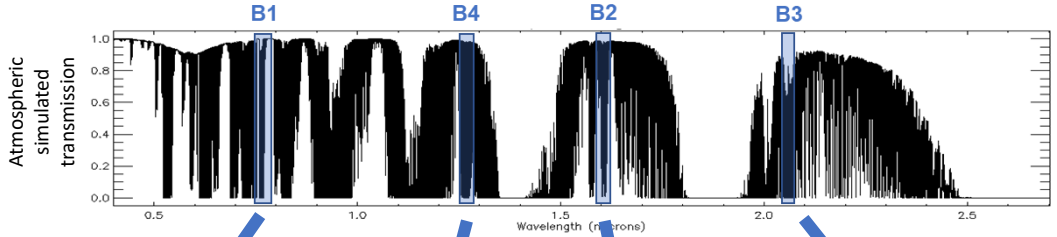
70m optical fiber

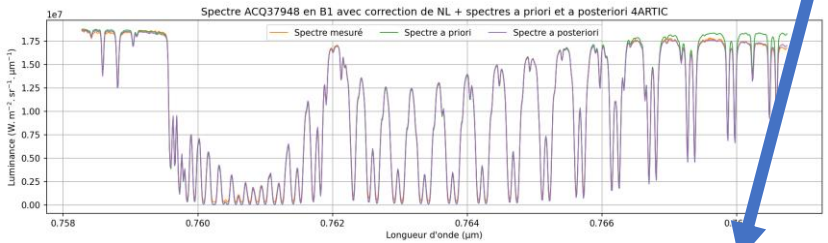
OGSE

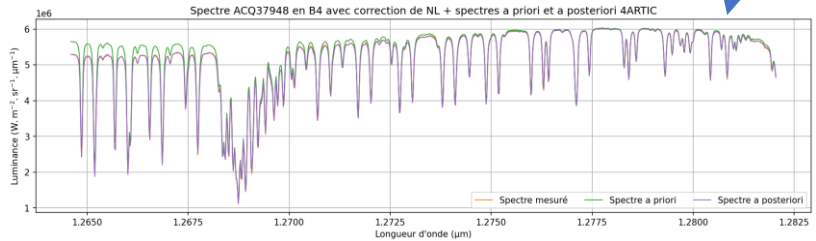


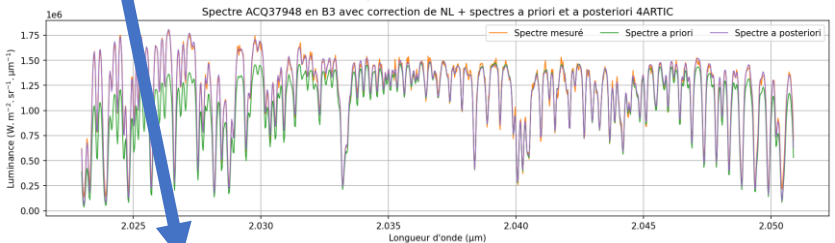
TVAC chamber

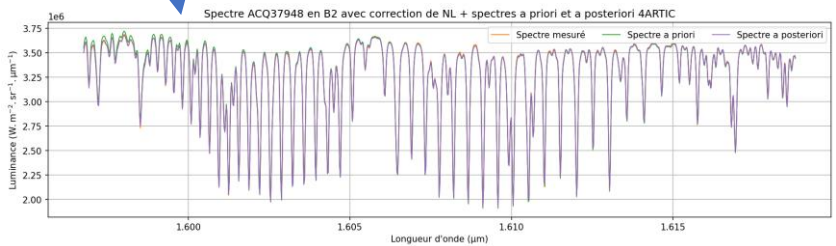
2 EM27 + AERONET











Level 1
- Good general shape
- Some residuals affecting continuum and line bottom
- Partly related to unstabilized detector during TVAC

Level 2
- Nominal observations: 2.5ppm bias
- Scene-variable observations: a few ppm bias
- Also partly relatied to unstabilized detector

MicroCarb works with EM27/SUN

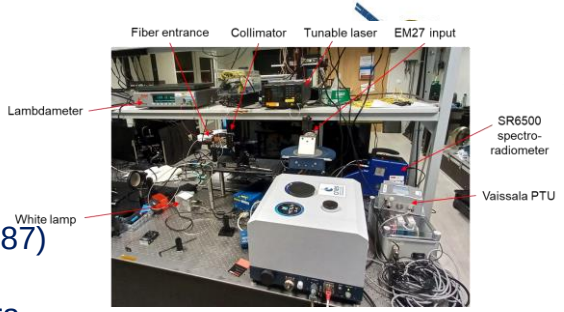
Rationale

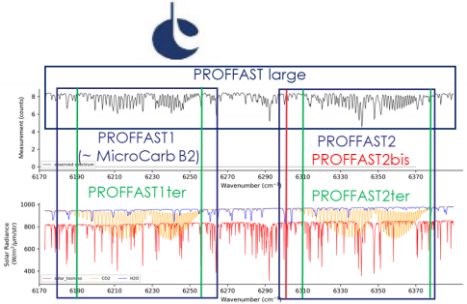
- CNES has owned an EM27/SUN (92) since 2018, now an second (287)
- We want to process MicroCarb's sun-looking measurements
- We want to train the MicroCarb methodologies on EM27/SUN spectra
- We want to increase our confidence in this important validation asset

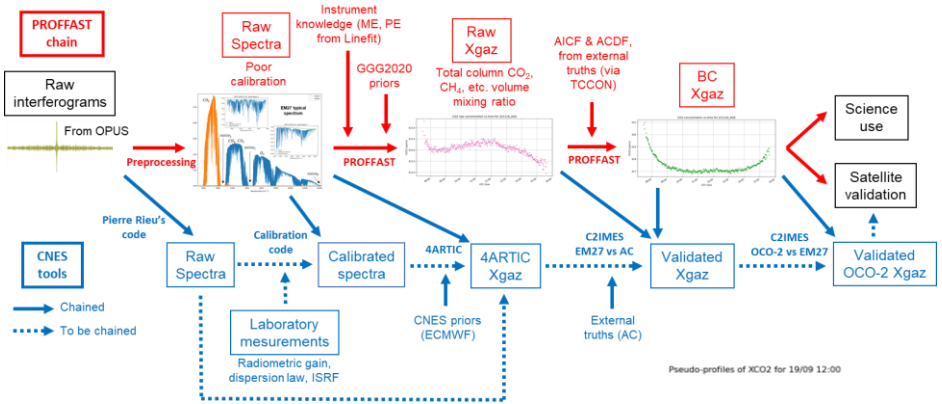
Works

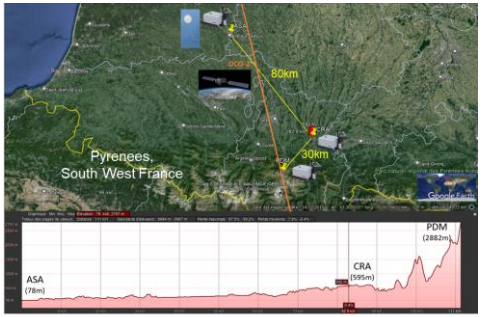
- Calibration of EM27/SUN (radiometry, ISRF) at CNES facilities
- MicroCarb retrieval tool 4ARTIC applied on EM27 spectra
- Validation of EM27/SUN (PROFFAST) vs AirCores
  - ΔXCO2 (92) = -0.21±0.64 ppm (15 flights)
  - ΔXCO2 (118) = -0.08±0.50 ppm (5 flights)
  - ΔXCO2 (130) = 0.01±0.43 ppm (21 flights)
- Specific campaigns (CNES with partners)
  - Cross-comparison of several EM27/SUN
  - Partial columns @ Pic du Midi top and bottom
  - Super-sites @ Aire sur l'Adour, Reims (EM27, AERONET, AirCore)
  - Regular comparison to satellites

➔ For next telecons!

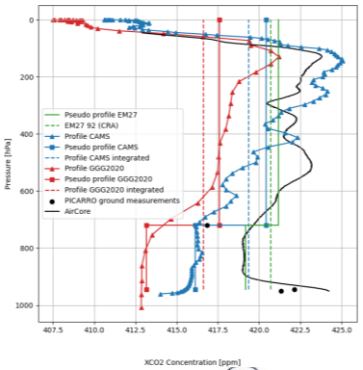








July 10th ➔ Sep 24th 2024, EM27 in automatic casings



Successful launch (summer 2025)

Fairing enclosure

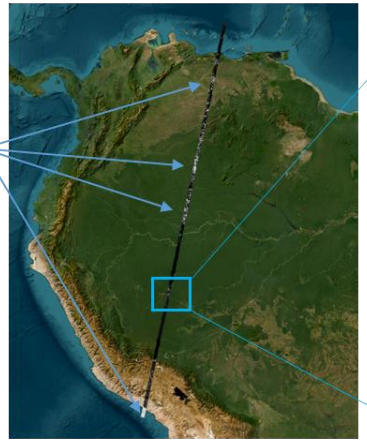
VEGA-C (VV27) launch
Kourou, French Guyana
26/07/2025 02:03 UTC

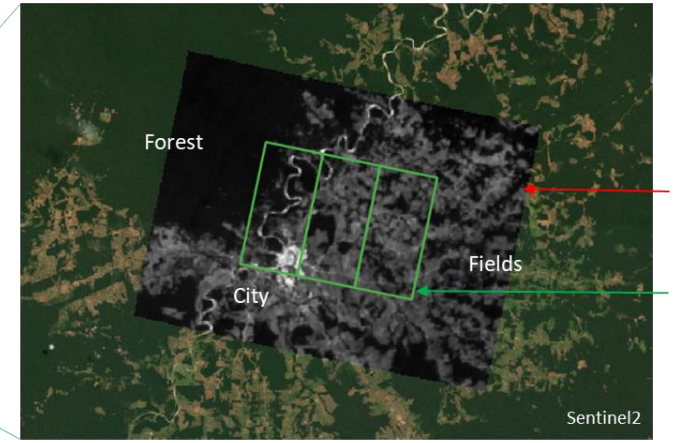
MicroCarb first light

IMAGER

Orbit 493
28/08/2025
15:03 UTC

Clouds





FrameSync 1349
City of Feijo, Brazil

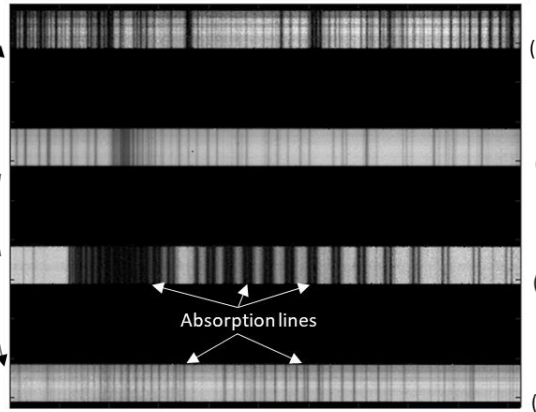
Imager
(27km x 18km)

Footprints of the
spectrometer
(3 x 4.5km x 9km)

SPECTROMETER

For the spectrometer footprints, 4 spectral bands (measured by a unique detector)

L1A spectra (detector)



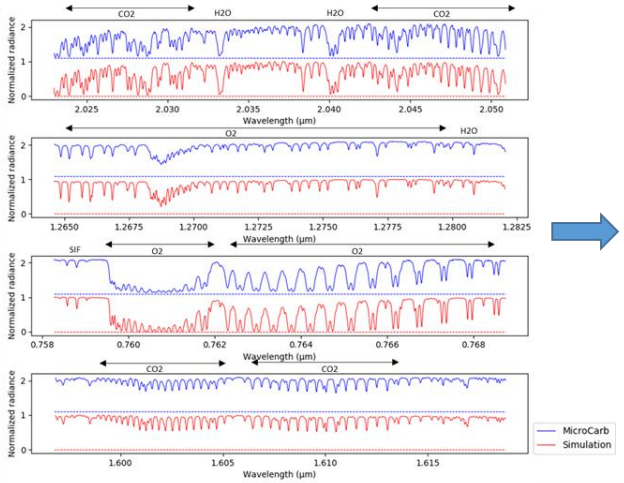
B3
(CO_2 @ 2.04µm)

B4
(O_2 @ 1.27µm)

B1
(O_2 @ 0.76µm)

B2
(CO_2 @ 1.61µm)

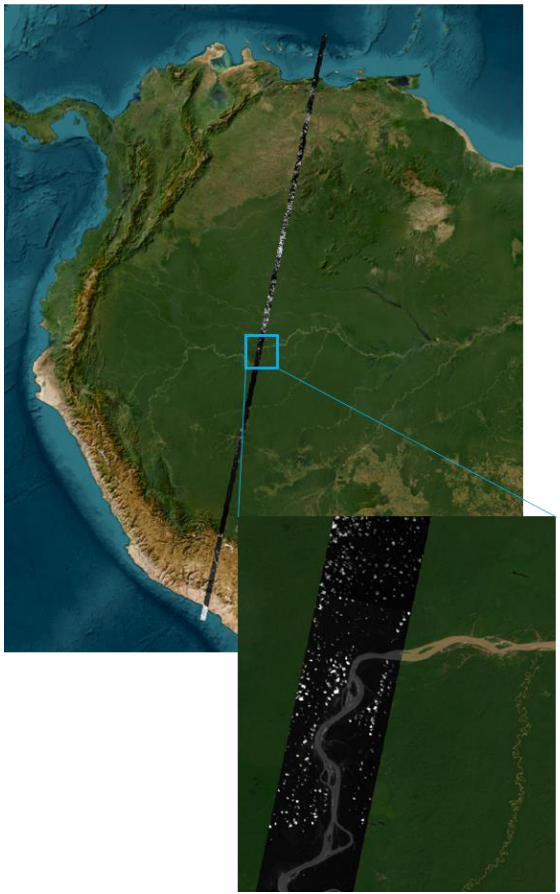
L1B spectra (averaged by ACT footprint)



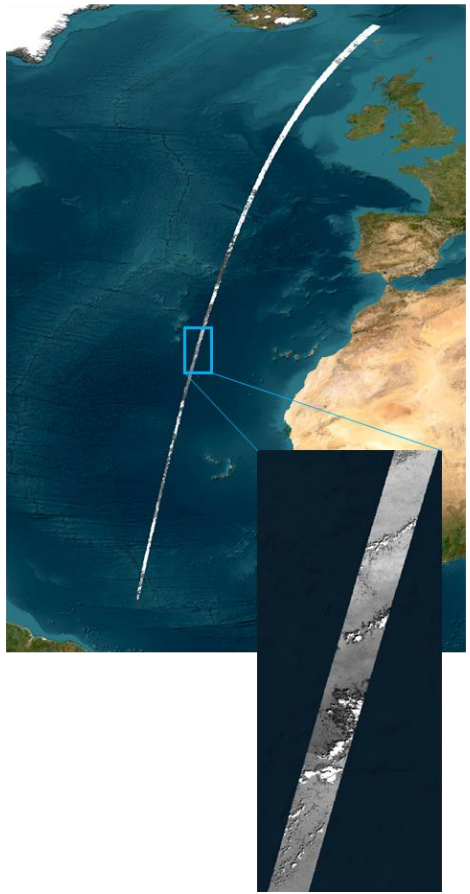
Coming soon:
CO_2
concentration

Observation modes

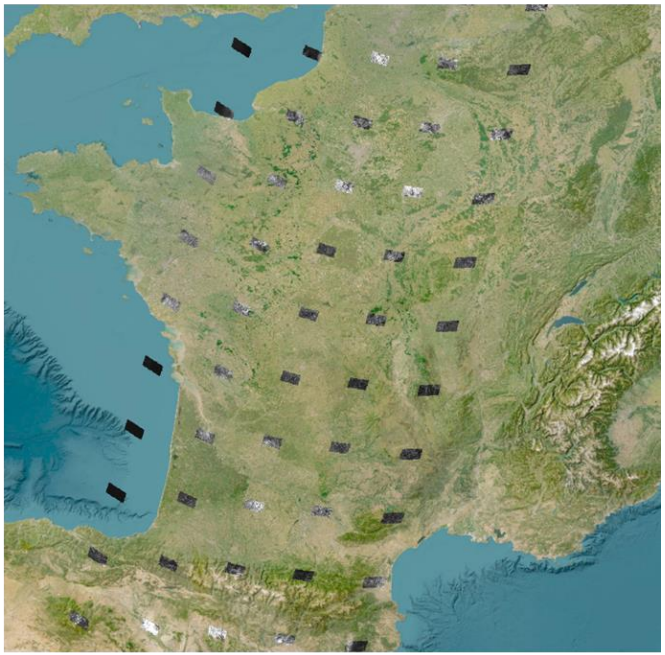
NADIR



GLINT

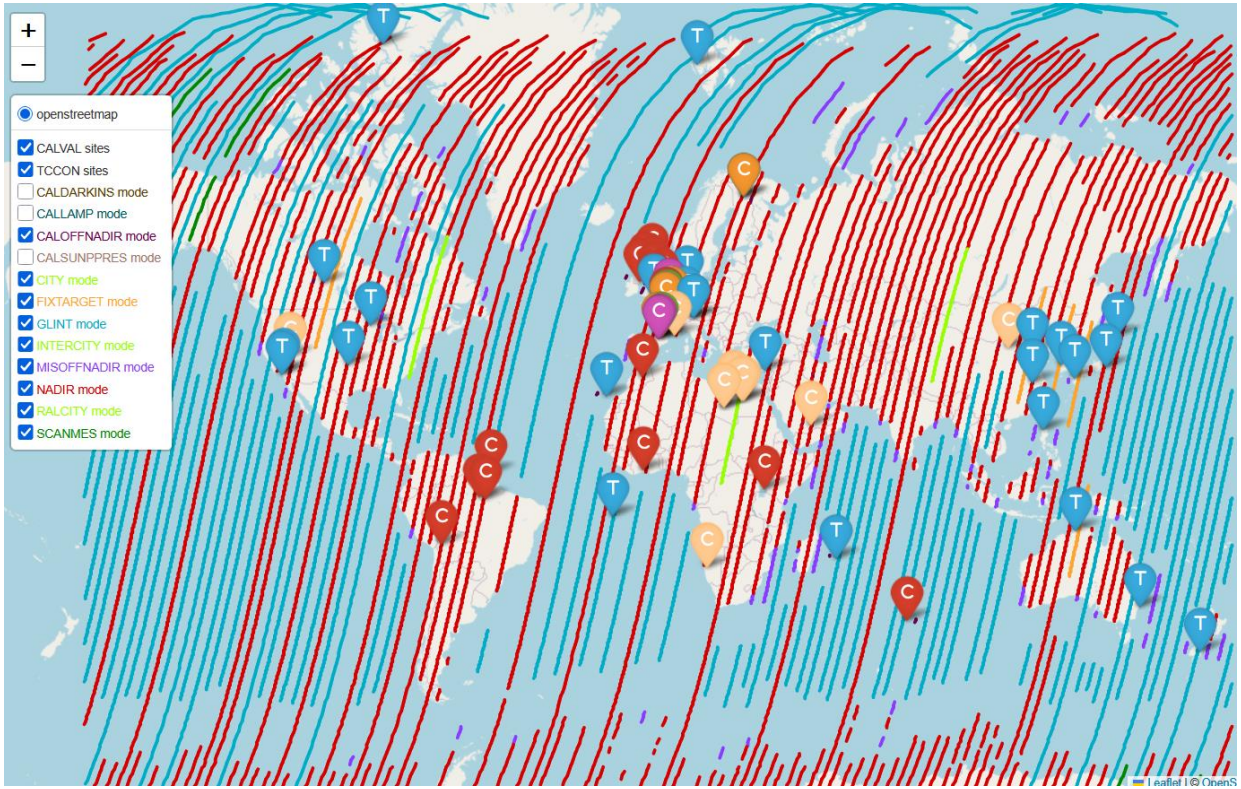


SCAN



TARGET and CITY modes also functional

Orbits from 15/09/2025 to 21/09/2025

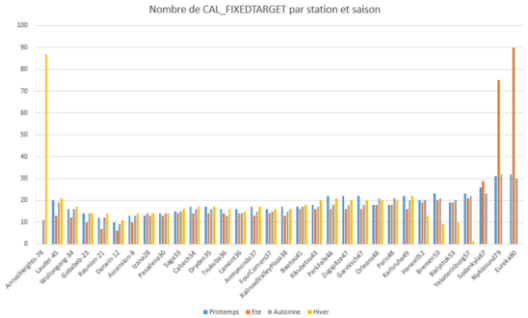


T = TCCON site
C = Other CALVAL site (EM27/SUN, deserts, SIF tower)

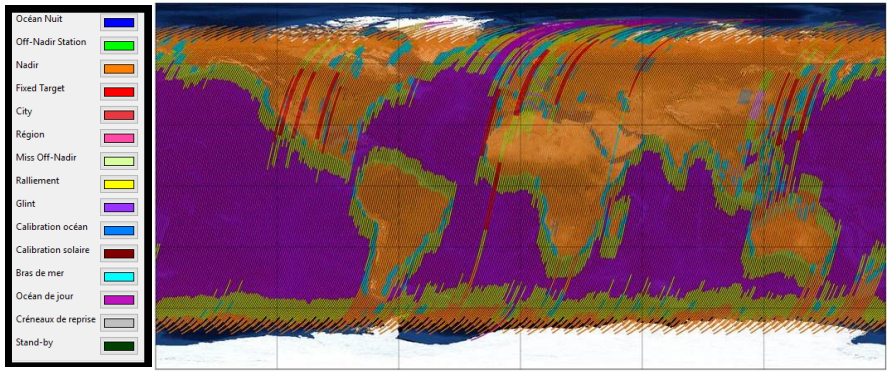
CALOFFNADIR modes (pointing mirror) to target EM27/SUNs

Opportunities and validation modes

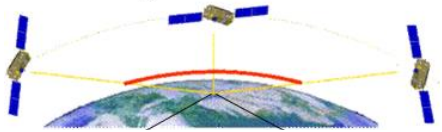
- **Opportunities with our orbit and ACT pointing mirror**
  - We can observe each location at least 1 per week
  - ~1 per month when considering clear sky
  - With 30 stations (e.g TCCON), MicroCarb will get ~2 clear sky opportunities / day = 700/year



Example of a mission plan
1 cycle = 368 orbits = 25 days



- **Observation modes**

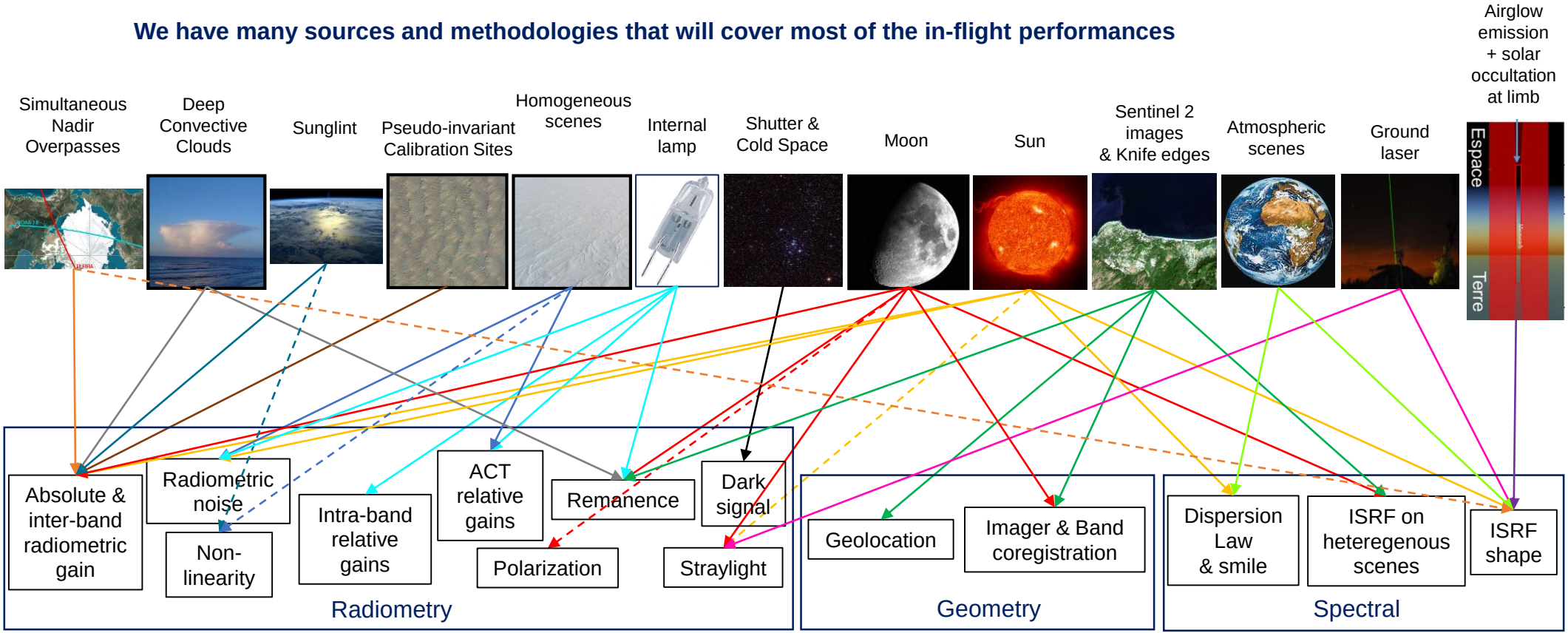
Fixed-Target (~OCO-2)	Off-nadir target
 Target Mode observes surface zenith angles between ±75° 	
• Pitch manoeuver to stay ~7min on the station • Brings much data at each overpass • But large cost for the mission availablity (~50%) ➔Numerous in cal/val, decrease in routine	• No pitch manoeuver, only an across track mirror shift • No cost for the mission availability • But brings only few data at each overpass ➔ As often as possible (cal/val and routine)

Cal/Val planning

Period	Phase name	Activities	Data
T0 = July 26th 2025			
T0 ➔ T0 + 10 days	**LEOP**		
T0 + 10days ➔ T0 + 60days	**Sat. and instr. in-flight commissioning**	Satellite functional tests Instrumental decontamination T0 +1day ➔ T0 + 3 weeks Instrument functional tests	
T0 + 1 month ➔ T0 + 7 months	**Cal/Val phase 1**	Tuning of instrument (Temperature, FOD) L1 & L2 processors started @ TEC L1 calibration, L1 algorithm tuning L2 first tests EUMETSAT first reprocessing @ T0 + 5 months	Acquisitions for Cal/Val Products only at TEC Samples to MAG
T0 + 7 months ➔ T0 + 12 months	**Cal/Val phase 2**	EUMETSAT online processing + 2 reprocessings L2 validation, L2 algorithm tuning L1 calibration consolidation	Acquisitions for Cal/Val and for mission Products of high quality to MAG
> T0 + 12 months	**Routine**	L4 works L1 & L2 validation and algorithm tuning goes on	All products freely downloadable from AERIS & EUMETSAT

Sources for L1 calibration

We have many sources and methodologies that will cover most of the in-flight performances



Large CNES heritage from imagery missions (PARASOL, Pleiades, S2)
Adaptations to MicroCarb

Low CNES heritage
On-going specific developments

L2 Cal/Val objectives

- **Quantification of the MicroCarb error**
  - Characterization of the systematic errors
    - Distinguish natural variations from measurement error
    - Instrumental defects / satellite / L1 processors / L2 processors
  - Update of the processing chains (parameters and algorithms)
  - Unvalid footprint flagging
  - Compliance status to mission requirement : random error, regional biases
  - Empirical bias correction

  ➔ **Massive statistics are uppermost important**
  - To discriminate the different bias sources
  - To make bias emerge from noise

- **XCO2 traceability to WMO standart (global bias)**
  - Important for users assimilating various products
  - Requires to reduce intermediate standards

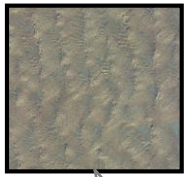
- **Quality check**

- **Validate secondary science products : aerosols, SIF, airglow, Psurf, XH2O, clouds**

Sources for L2 validation

XCO2 : priority to validated, regular, network, affordable with low carbon budget sources

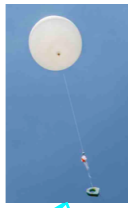
Homogeneous CO2



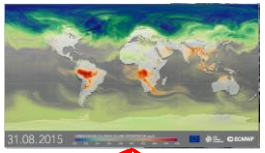
TCCON

EM27/SUN

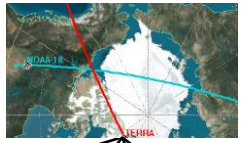
AirCore + RS



ECMWF & CAMS models



Simultaneous Nadir Overpasses OCO-x, GOSAT-x, EarthCare, MODIS

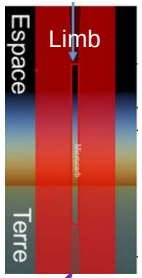


AERONET

Laser MiniMPL

Fluorescence masts

Ocean



XCO2 random error

XCO2 bias

CO2 profile

XCO2

Psurf

XH2O

Psurf, T, XH2O

AOD

Aerosol Type

Aerosol Profile

Aerosols

Amplitude

Fluorescence

Amplitude

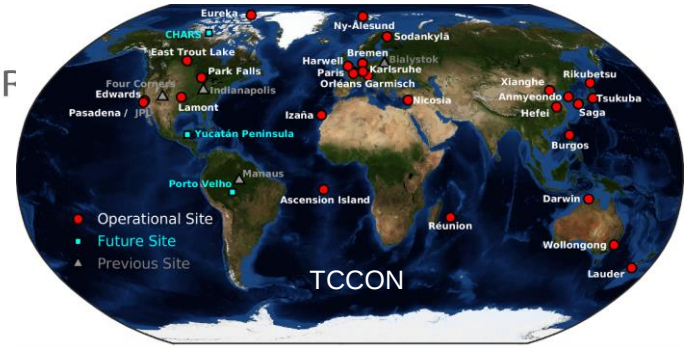
Airglow model

Airglow

Massive statistics are uppermost important

- To discriminate the different bias sources
- To make bias emerge from noise

COCCON for MicroCarb

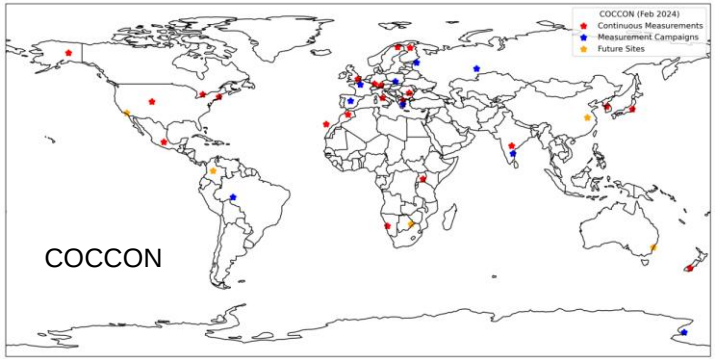


- **TCCON is of high interest, but with limitations**
  - ~30 stations
  - Heterogenously dispatched and mostly in Northern Hemisphere

  ➔ Representativity in atmospheres and availability for satellites (incl weather) deserves improvement

- **COCCON**
  - ~40 sites in COCCON network (https://www.imkasf.kit.edu/english/3884.php)
  - ~20 sites in areas deprived of TCCON stations ➔ complementary to TCCON, therefore very useful for us

  E.g. Bologna, Boulder, Daejeon, Fairbanks, Gobabeb, Harvard, Kiruna, Koror, London, Magurele, Mexico City, Roma, Seoul, Spain sites, St Petersburg, Thessaloniki, Toronto, Yekaterinburg
  - Sites collocated with TCCON ➔ also useful to scale both networks



- **EM27/SUN not referenced in COCCON**
  - Some Fr and UK sites (involved in MicroCarb science team)
  - Others?

- **We would like to get data from most EM27/SUN in the world!**

Needs towards COCCON

(Similar needs as expressed to TCCON and AirCore communities)

- **Needs**
  - Supply of only measurements of the day of the MicroCarb overpass: complete day (O), ±1hr around the overpass (T)
  - Supply of Xgaz with all outputs from PROFFAST, last official version PROFFAST
  - Ideally supply of raw measurements (OPUS, PTU, maps) to enable us to reprocess with further versions
  - Ideally short timeliness delivery (2 weeks (O), 4 weeks (T))
  - Starts mid-september 2025, enforced for period 01/01/2026 - 31/12/2026

- **MicroCarb overpasses warnings**
  - **For casual measurements, AERIS provides the mission plan**

  (https://www.icare.univ-lille.fr/asd-content/DATA/LIENS/MICROCARB/CARB_MISSION_PLAN_MAP/latest)
  - **Scheme for TCCON**
    - Every week, CNES sends an “information email” for opportunities in next 2 weeks
    - Every day, CNES sends a “confirmation email” for actual observation on D+1, based on operational status (from web site) and on weather forecast
    - After observation, CNES sends a “feedback email”
  - **For COCCON, choice of**
    - No warning ➔ only OFFNADIR targets on operational sites
    - Or manual warning (partially similar to the TCCON process) ➔ compulsory for FIXED-TARGETs

- **Data delivery**
  - From COCCON : Up to now no FTP server available globally at CNES ➔ Either local FTP server or temporary links
  - From MicroCarb : freely released in routine within ~2 days

MicroCarb and COCCON

We look forward to get data from most EM27/SUN in the world!

➔Please feel free to contact us if you are willing to take part to MicroCarb's validation ☺
denis.jouglet@cnes.fr
christel.guy@cnes.fr

From our side we also plan to contact PIs of some sites or national networks (but we need a contact list)