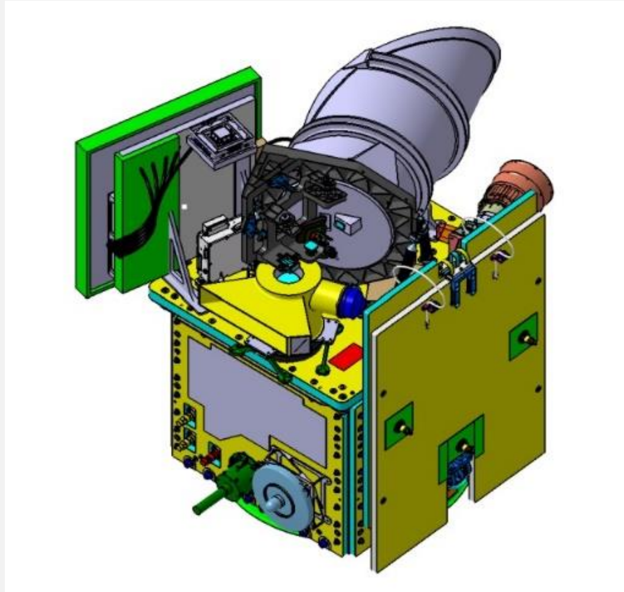
THE MICROCARB PERFORMANCES (L1 & L2)



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ABSTRACT

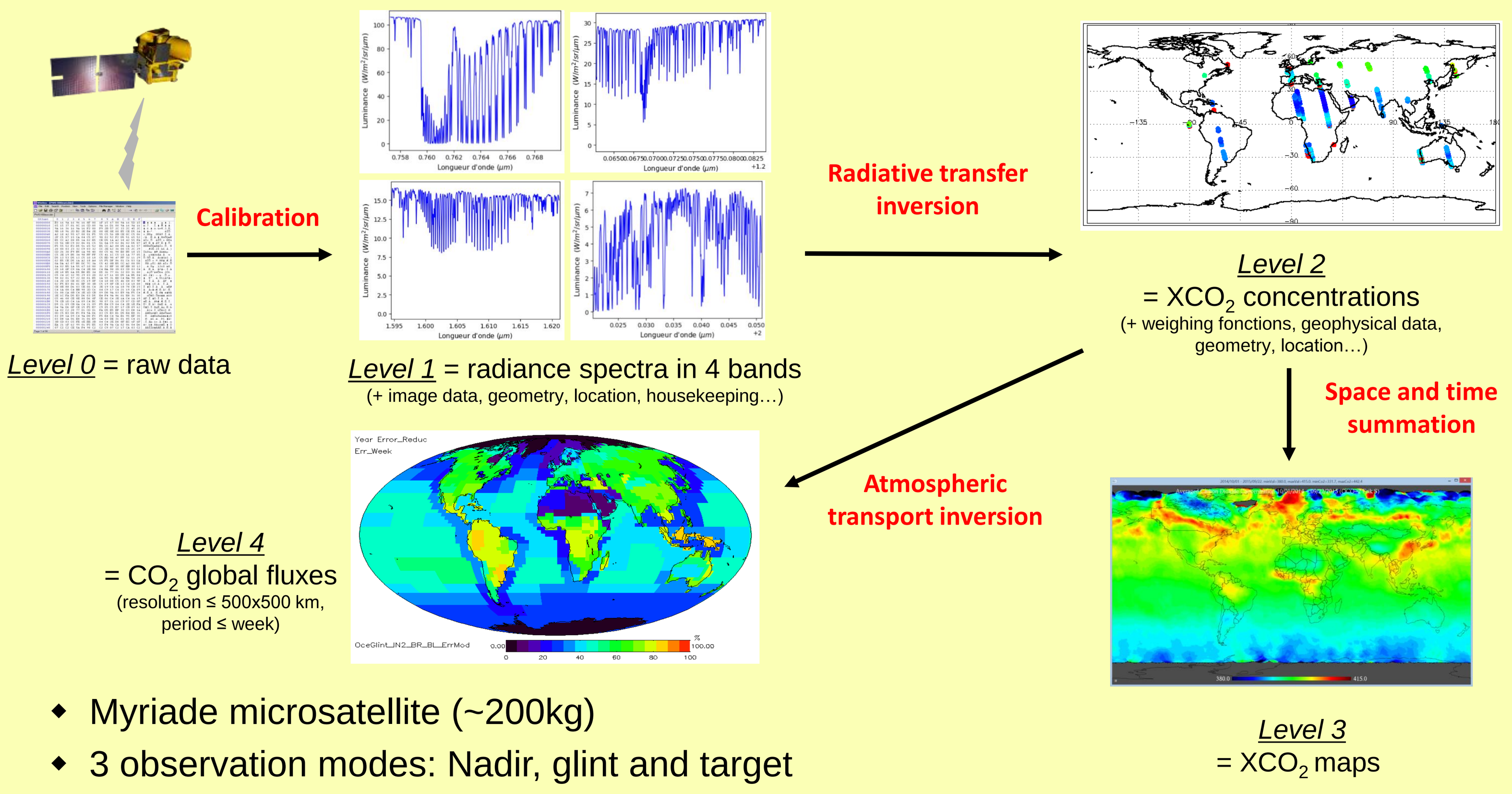
The objective of the CNES MicroCarb mission is to retrieve the CO_2 dry air mass mole fraction (XCO_2) with a high accuracy, in order to better quantify the sources and sinks of CO_2. This high accuracy has been the main driver for the requirements applied to the instrumental and satellite design (section 1) as well as the ground segment.

This poster presents the algorithms for the L1 and L2 data processing (section 2), and lists all the contributors the XCO_2 accuracy in terms of random error and bias (section 3). Tests of the L2 algorithm with the OCO-2 L1b data are also presented (section 4).

An insight of the MicroCarb mission is to acquire a second O_2 band at 1.27 µm to improve the retrievals in presence of aerosols. This poster also exposes the on-going works to manage the airglow pollution (section 5).

1 – THE MICROCARB MISSION

- Objective of the MicroCarb mission: globally measure the column integrated volume mixing ratios of CO_2 to better constrain the natural sources and sinks.
- From MicroCarb measurements to the global fluxes:

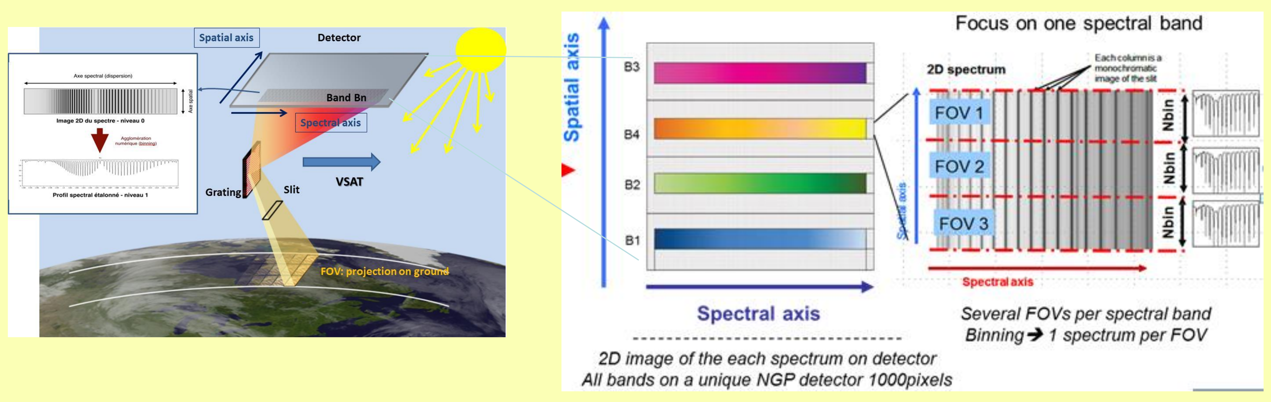


- Myriade microsatellite (~200kg)
- 3 observation modes: Nadir, glint and target
- Mission main facts:

Parameter	Value
Orbit	649 km - 13h30 LTAN
Swath	13.5 km, 3 footprints
Elementary footprint	4.5 x 9 km² at nadir
CO_2 random error	< 1 ppm
CO_2 regional bias	< 0.2 ppm
Launch time	March 2021

L1 performances	B1 (O_2)	B4 (O_2)	B2 (CO_2)	B3 (CO_2)
Band center (nm)	763.5	1273.4	1607.9	2035.7
Band width (nm)	10.5	17.6	22.1	25.3
Spectral resolution (λ/Δλ)	25,500	25,900	25,800	25,900
SNR for median radiance (per channel)	285	378	344	177

- The instrument is a compact concept based on a grating. The 4 spectral bands are acquired by a unique telescope, spectrometer, grating and 2D detector.



2 – DATA PROCESSING

- **L1A (pixel level)**
  - Radiometric calibration: absolute gain (from solar acquisition), inter-pixel gain (from lamp), dark subtraction (from shutter acquisition), non-linearity correction, straylight correction
  - Spectral calibration: computation of the spectral law (from solar acquisition)
  - Geometric calibration of the imager (from orbitography and attitude)
- **L1B (footprint level)**
  - Binning of the across-track pixels radiometry
  - Binning of the spectral law and ISRFs
  - Correction of ISRFs for ACT and ALT non-uniformity (use of the ACT pixels and intermediate readings of the detector)
  - Geometric calibration of the footprint
  - Spike detection
- **L1C (footprint level corrected using geophysical data)**
  - Computation of a theoretical best known spectrum: Psurf from PlanetObserver + ECMWF, CO_2 from CAMS, T & H2O from ECMWF, albedo from Sentinel 2 L2, aerosols from CAMS
  - Update of the spectral law thanks to the correlation on an atmospheric spectrum
  - Radiometric correction of polarization residual
  - Geometric calibration of polarization scrambler effect
  - Geometric refinement by correlation with Sentinel 2
  - Cloud detection using imager (comparison to S2 clear sky) and sounder (comparison of retrieved Psurf to a priori Psurf; intra-FOV maps of Psurf and H_2O)
- **L2**
  - Filtering on spikes, cloud amount, non uniformity
  - Inversion using optimal estimation (Rodgers 2000) done by 4ARTIC
  - Radiative Transfer from 4AOP (GEISA for spectroscopy, LIDORT / VLIDORT for diffusion)
  - State Vector: 20 CO_2 levels, 20 H_2O levels, Psurf, albedo and slope in each band, 3 aerosol parameters (AOD @ 0.76µm, angstrom coefficient, altitude of a Gaussian vertical distribution), fluorescence, airglow, instrumental parameters
  - Computation of XCO_2

3 – PERFORMANCE BUDGET

- **On going complete XCO_2 accuracy theoretical estimation**
  - Based on instrument and satellite performances
- **List of all instrument, satellite and processing contributors**
  - Determination of error nature (random error, global bias, regional bias = bias related to the scene or low temporal scales)

Main contributors to mission performance

Radiometry
Radiometric noise (SNR)
Absolute gain residual
Channel to channel gain residual
Dark signal residual
Non-linearity residual
Instrumental polarization residual
Spectral
Shape of the ISRF
Limited knowledge of the ISRF
Limited knowledge of the dispersion law
Geometry
Limited knowledge of geolocation
Limited knowledge of the FOV spread function
Intra-band misregistration
Inter-band misregistration
Limited knowledge of VZA
L2 processing
Limited *a priori* knowledge of CO_2
Limited knowledge of weather (H_2O, Psurf, T) and DTM
Limited knowledge of the solar spectrum
Spectroscopy error
Residue of cloud cover
Impact of aerosols
Impact of 1.27 µm airglow
Impact of 0.76 µm vegetation fluorescence
Impact of 4AOP calculation accuracy

- **Transfer of L1 contributors to L2**
  - Random error transfered by a posteriori covariance

$$\hat{S} = (K^T S_\varepsilon^{-1} K + S_a^{-1})^{-1}$$

State vector a posteriori covariance matrix ($\hat{S}$); Jacobian matrix (K); Noise covariance matrix (S_ε); State vector a priori covariance matrix (S_a)

  - Results of the end of phase B →

	X_{CO2} Random Error (ppm)
A priori	16.79
Min radiance (SZA=65°, refl = 0.13, 0.1, 0.1, 0.05)	1.5
Median radiance (SZA=36°, refl = 0.25, 0.2, 0.2, 0.1)	0.55
Max radiance (SZA=0°, refl = 0.55, 0.55, 0.55, 0.55)	0.22

  - Bias transfered by gain matrix

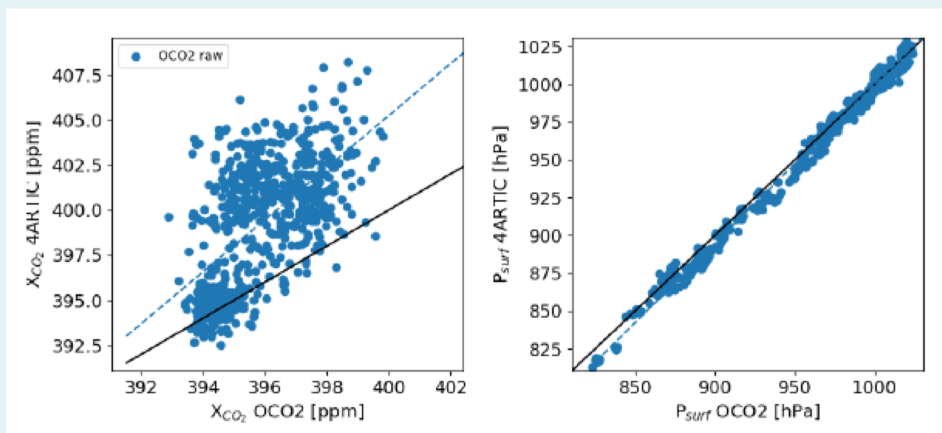
$$Bp = G * Bm \quad \text{with} \quad G = \hat{S} K^T S_\varepsilon^{-1} = \frac{\partial \hat{x}}{\partial y}$$

Bias on L2 (Bp); Gain matrix (G); Bias on L1 (Bm)

- **Application to an orbital scene database representative of MicroCarb**
  - Study of the occurrence of the worst scenes
  - Determination of the correlation between defects

4 – INVERSION OF OCO-2 L1B WITH 4ARTIC

- We test the 4ARTIC XCO_2 retrieval to the OCO-2 L1b data
- Work by Leslie David, François-Marie Bréon from LSCE
- Current work:
  - Clear sky, nadir mode
  - Comparison to L2 OCO-2
- Coming work:
  - Comparison to TCCON (target mode)
  - Aerosol loaded scenes
  - Estimation of fluorescence
  - Glint mode

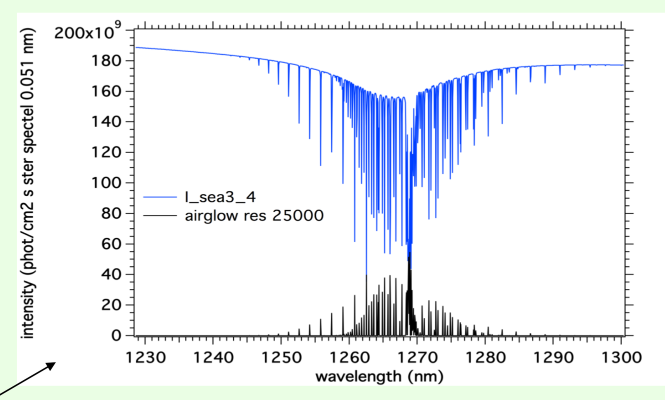


P_{surf} [hPa]	X_{CO_2} [ppm]	Residus [%]		
		O_2	wCO_2	sCO_2
2.22 ± 5.55	-3.41 ± 2.84	0.39	0.34	0.59

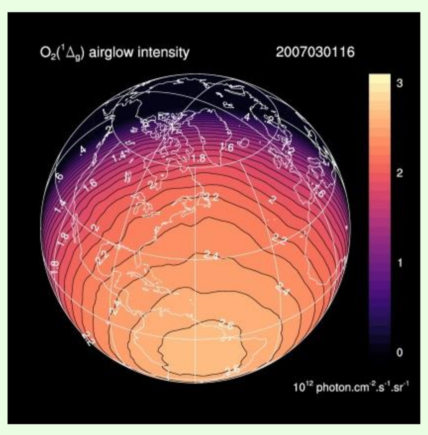
5 – SPECIFIC STUDY ON AIRGLOW AT 1.27 µm

- **CNES decided to acquire a fourth spectral band, the 1.27 µm O_2 band, to improve retrievals in aerosol loaded conditions**
- **This band is known to exhibit a strong airglow emission due to the photodissociation of mesospheric O_3**
- **Ignoring airglow in the inversion leads to strong biases on Psurf (~80 hPa)**

→ On going study by LATMOS and ACRI on the 1.27 µm band



- **Modelling of the emission:**
  - Spectroscopy and spectral shape of airglow (impacts centers of O_2 absorption lines)
  - A Chemical Transport Model (REPROBUS by F. Lefevre) can provide estimates of airglow
  - Comparisons to SCIAMACHY limb and nadir measurements confirms the model quality (current error of 20%)



- **Estimation in MicroCarb spectra**
  - Airglow can be efficiently estimated as an element in 4RTIC state vector
  - → XO_2 residual biases are very low (0.01 hPa)
  - Possibility to remove the most contaminated channels if necessary