Status of the CNES / MicroCarb small satellite for CO_2 measurements

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on behalf of the MicroCarb team
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MICROCARB MISSION OBJECTIVES

MicroCarb will measure the vertically integrated CO_2 concentrations

- To quantify CO_2 surface fluxes over the globe at regional scales
- To identify and monitor global carbon sources and sinks
- To better understand the mechanisms in oceans and vegetation

Mission requirements focused on the quality of the CO_2 concentration measurements => **priority given to accuracy** (< 1 ppm) rather than high spatial resolution or sampling

The payload shall consist of a **compact passive instrument** for an accommodation:

- on a Micro-Satellite (CNES Myriade Evolutions Bus)
- or on a partner platform flight opportunity (autonomous payload)

MICROCARB PHASE A RANGE

MicroCarb is currently ending Phase A

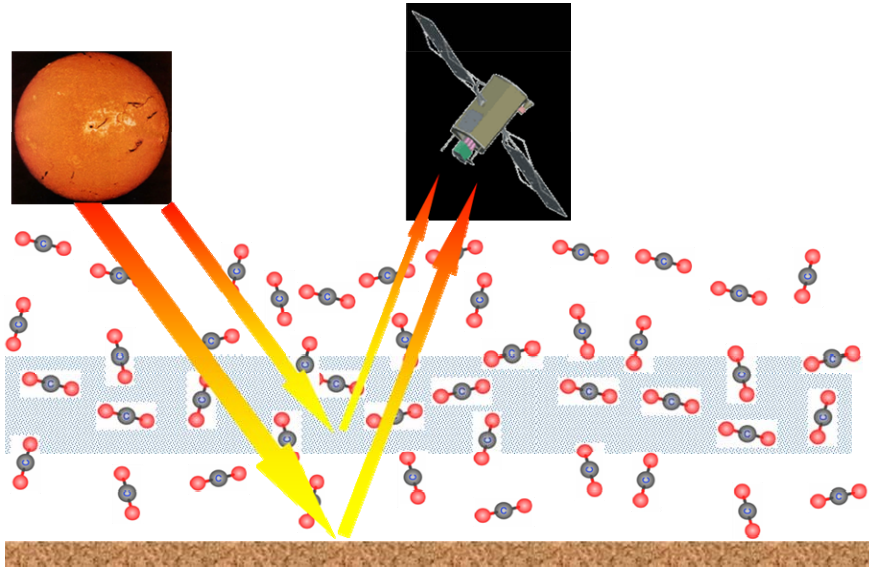
- Objective: to prove the feasibility of the mission
- Lead by CNES from early 2011 to late 2013

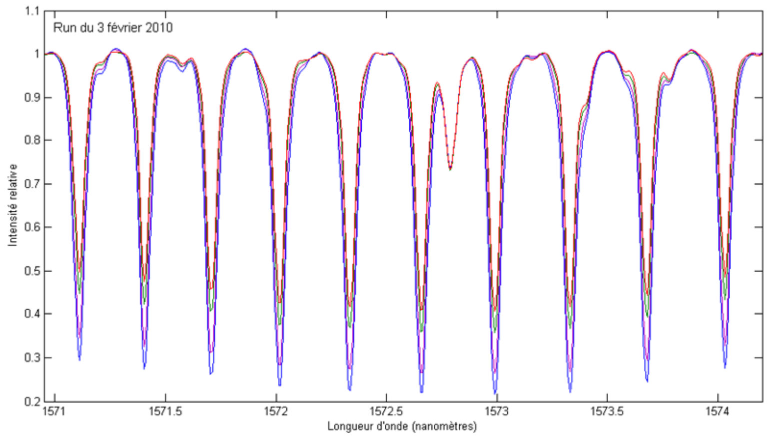
- Mission requirements defined by the MicroCarb Science Group
  - F-M Bréon (PI) from LSCE, C. Camy Peyret, S. Payan, F. Chevallier etc …
- 2 competitive industrial analyses (Thales Alenia Space and Astrium)
- Work with technology companies

- Range of phase A:
  - Mission and Satellite/Instrument requirements from CNES / LSCE
  - Instrument concept selection: grating spectrometer (vs static interferometer)
  - Instrument and satellite design
  - Retrieval algorithms development
  - Evaluation of performances at different levels
  - System (Flight Operation and Data Mission Center) preliminary architecture

THE MICROCARB MEASUREMENT

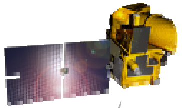
- CO2 global fluxes cannot be remotly sensed
- MicroCarb senses the solar flux reflected by the Earth in 3 NIR and SWIR bands:
  - B1: 0,76 µm O2 band (surface pressure, optical path length, aerosol distribution)
  - B2: 1,61 µm CO2 band (almost linearly dependent on [CO2])
  - B3: 2,06 µm CO2 band ([CO2], sensitive to clouds, aerosols, water vapor…)



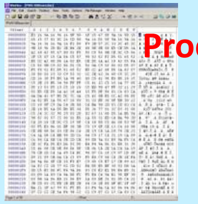


CO_2 absorption bands around 1.6 µm

- These spectral signatures give access to the CO2 total column concentration

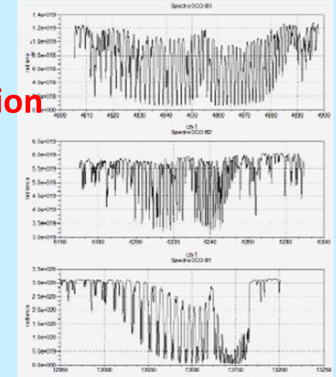


MICROCARB PRODUCTS



Processing, Calibration

Level 0 = Raw data



Level 1 = 3 bands calibrated spectra
(+ image data, geometry, location, housekeeping…)

CNES

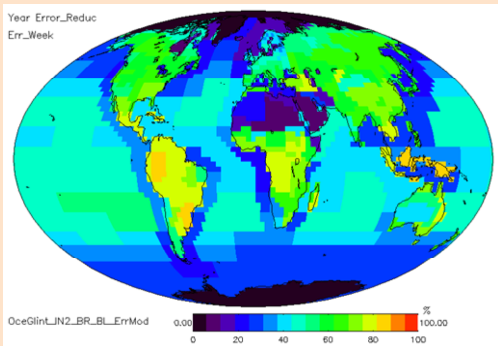
Inversion of the Radiative Transfer Model (Optimal Estimation from Rodgers)

4ARTIC

Level 2
= CO_2 concentrations
(+ weigh fonctions, geophysical data, geometry, location…)
Global coverage

Level 3
= XCO_2 maps

Inversion of the Global Circulation Model
LMDz



Level 4
= CO_2 global fluxes, sources/sinks
(resolution ≤ 500x500 km, period ≤ week)

Labs

- The L2 performances required by scientists are very high to be able to detect slight spatial gradients or temporal evolutions

➔ [CO2] accuracy < 1ppm/400ppm = 0.3%!

➔ Requires a very high quality spectrometer

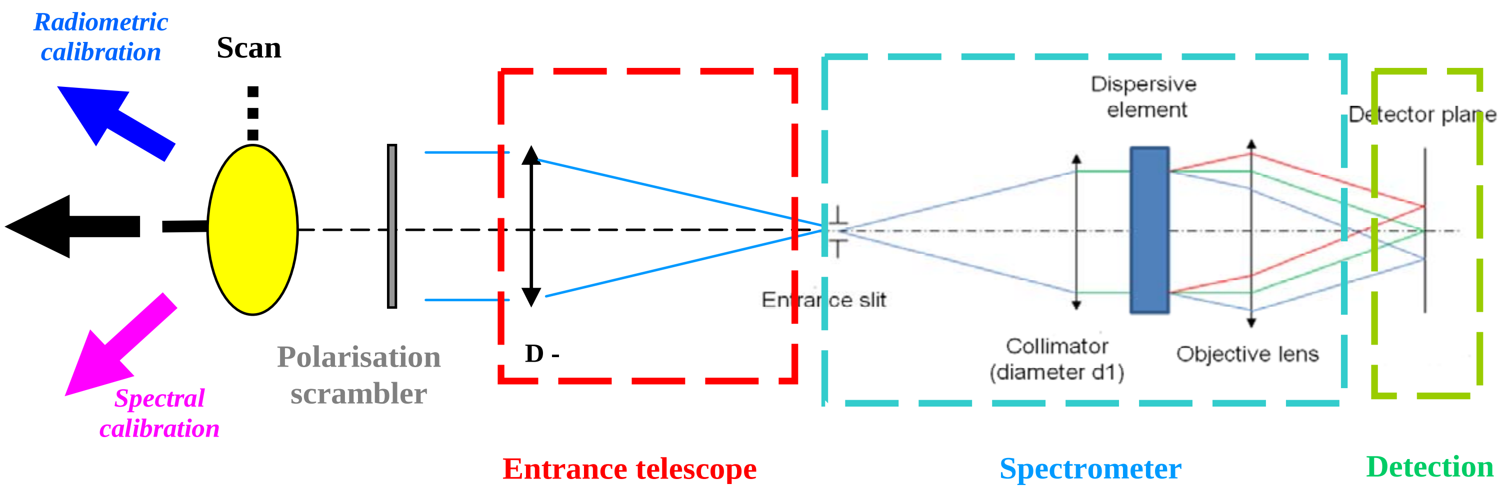
- High radiometric and spectral resolution
- High calibration accuracy

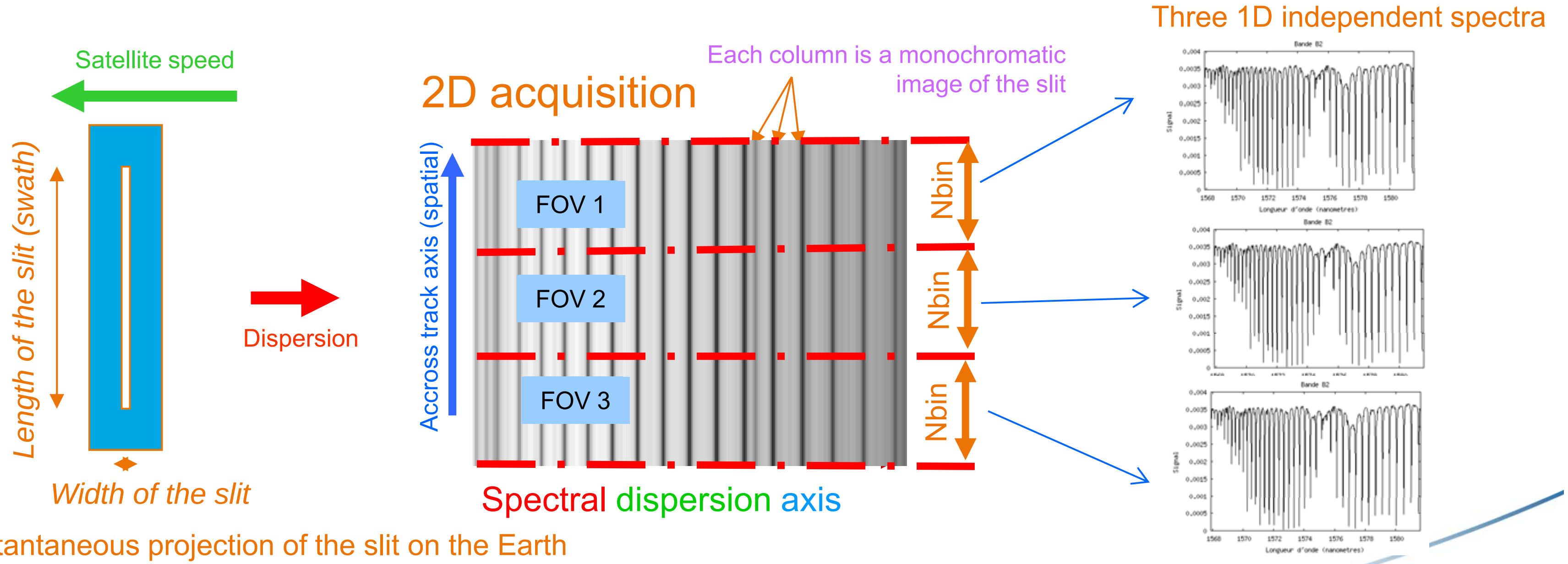
MICROCARB MISSION SUMMARY

Specification	MICROCARB
Orbit	705 km, polar, 13h30 sun-synchronous
Revisit time/ orbits	16 days / 233 orbits
Observation Mode	Nadir, Glint, Target (TCCON station, field campaign)
CO_2 sensitivity	Total Column, weighting functions peaking at surface
CO_2 uncertainty	< 1 ppm, without any regional biases
Instrument Technology	Passive instrument, Grating spectrometer 3 spectral bands (0,76µm; 1,6µm ; 2µm)
Horizontal resolution	~ 25 km^2
Nber of pixel across track	5 (swath 15 km)
Radiometric resolution (SNR)	200 to 500
Spectral resolution	25,000 to 42,000
Spectral widths	30 to 90 cm^{-1}
Polarisation	Linear instrumental polarization < 0.1% (glint)
Cloud imager wavelength	0.625 µm
Launch date target	2018
Nominal lifetime	3 years

Industrial trade-off using a performance factor

MICROCARB INSTRUMENTAL CONCEPT





IFOV = instantaneous projection of the slit on the Earth
FOV = IFOV temporally integrated

SOME CNES TOOLS DEVELOPED DURING PHASE A

- An experimental optical breadboard
  - To validate the instrumental concept
  - To get experience about potential instrumental artifacts
  - To test the main technological developments. Ex: new grating, polarisation scrambler

- Numerical tools

Geophysics

Radiative Transfer Model

4AOP-SWIR

Gaseous absorptions
Rayleigh and aerosol diffusion
Polarization

Atmo. spectrum

Instrumental design

Instrument simulator

Includes instrumental signatures, defects, calibration scheme

MicroCarb realistic spectrum (L1)

A priori knowledge

Spectra inversion

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Also tested with real data (from GOSAT and TCCON)

CO_2 concentration + performance (L2)

A priori knowledge

Fluxes inversion

(L4)

Realistic spatial and temporal coverage

MAIN RECENT ACHIEVEMENTS

Several key preparatory activities have been achieved:

- Improvement of the CNES optical breadboard and instrument simulator
- Improvement and validation of RTM and retrieval tools, ex: inversion incl. aerosols
  - See **oral presentation from Camy-Peyret et al.** on Thursday afternoon
- Consolidation of the level 1 requirements
- Consolidation with industry of the instrument design focused on:
  - Calibration (radiometric and spectral)
  - Level 1 correction algorithms
  - Polarization
- Evaluation of the level 1 (incl. pseudo-noises), 2 and 4 performances
- Risk mitigation through technological validation:
  - Polarization scrambler
  - Large European “echelle” grating feasibility
  - Optimization of a cryocooler machine for micro satellite
  - Characterization and improvement of detectors
- Etc.

MICROCARB PHASE A MAIN CONCLUSIONS

A reference design for Satellite and Instrument has been proposed by each competitive company (final delivery in May 2013!)

Main conclusion of both studies :

- **No show stopper** identified concerning the feasibility of a Micro-Satellite fulfilling the MicroCarb mission requirements
- 60 < mass < 70kg, 60 < power < 100W, volume OK for Soyuz ASAP external position

Current estimated performances:

- Level 1 industrial performances:
  - **Compliant with L1 requirements**
  - Technology Readiness Levels are acceptable
- Level 2 CNES estimated performances: [CO2] accuracy
  - **Similar to OCO-2**
  - Between 0.2 and 1 ppm in cases without aerosols
  - Regional biases estimation under progress (and its dependence with geophysics)
  - **See poster Jouglet et al. for more details**
- Level 4 LSCE estimated performances: CO2 surface flux accuracy
  - High level of knowledge improvement
  - Performance ~ OCO-2 (slightly lower due to number and size of FOVs)
  - Biases estimation under progress

MICROCARB AUTONOMOUS PAYLOAD

In parallel to the Micro-Satellite implementation solution, CNES asked industry to explore the feasibility of a **MicroCarb Autonomous Payload**

- Objective: to enable the accommodation on potential partner platform
- Assumption : reuse most of the building blocks from the current instrument
- Autonomous = **with Stand Alone pointing capabilities**
  - Requires **pointing mirror mechanisms** to fulfill the glint and target modes

- Final consolidated conclusions of the study :
  - Demonstration of the feasibility of a Stand Alone compact Payload
  - **Payload assessed performances close to Micro-satellite performances**
  - **Compliant with the MicroCarb mission requirements**

CONCLUSIONS

CNES Microcarb phase A was challenging : to reach (as close as possible) an "OCO2-like" CO2 performance in a constrained budget

With a Phase A initiated in 2011, consolidated results available :

- A compact instrument concept fulfilling a CO2 mission ambitious objectives is feasible
- Accommodation on a micro-satellite or on an autonomous payload

Phase A will finish at late mid 2013 (PRR)

- Some on-going activities after PRR: L2 inversion improvements, instrument optimization
- On-going coordination with other Greenhouse gazes missions
- Decision for phase B taken in 2014, after a CNES scientific prospective meeting
- Open to discussion to define cooperation with potential partners (provide a carrier satellite for the payload, development of subsystems of the micro-satellite mission, etc.)

Schedule allows a launch in 2018:

- MicroCarb shall bring a European contribution to the Carbon flux measurements from space
- MicroCarb could be a precursor for a long-term future operational CO_2 monitoring system

  ➔ constellation of Micro-Satellites / secondary payloads onboard operational platforms


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Thank you for your attention –
More information on
http://smsc.cnes.fr/microcarb/