Presentation at IWGGMS-15, Sapporo

The MicroCarb Project: recent achievements and review of the project status

CEOS AC-VC-15 Tokyo 10-12 June 2019

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Presented by Claude CAMY-PEYRET (IPSL) – member of the MicroCarb « Groupe Mission » (PI: F.-M. Bréon)

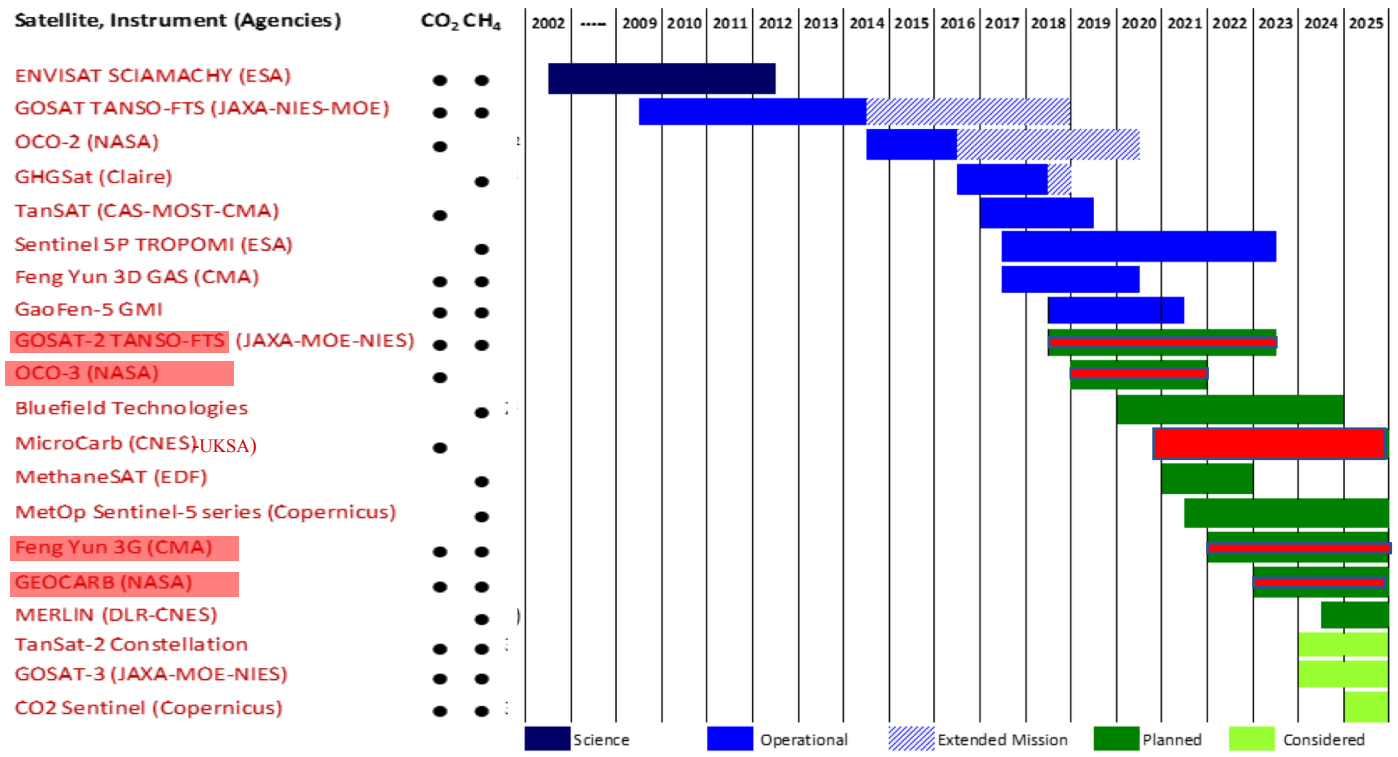
MicroCarb Mission

- Scientific mission → global XCO_2 and natural fluxes
- Use of O_2 atmospheric A-band (P_{surf}, aerosols, SIF)
- On ground resolution
  - ✦ 3 simultaneous samples 4.5 x 9 km (@nadir)
  - ✦ Exploratory mode: imaging with higher resolution 2 km x 2 km over limited area (40 km x 40 km)
- Compact instrument . Compatible with microsatellite < 200 kg

- Orbit
  - ✦ SSO – 649 km – 13h30 LTAN
  - ✦ Cycle: 25 days - 7 days sub-cycle
- Operations
  - ✦ Launch: 2021
  - ✦ Life time: 5 years
- Launch:
  - ✦ as an auxiliary payload (Ariane, Vega)

Spectral Performances	B1 (O_2)	B4 (O_2)	B2(CO_2)	B3(CO_2)
Central Wavelength (nm)	763.5	1273.4	1607.9	2037.1
Bandwidth (nm)	10.5	17.6	22.1	28,1
Mean Spectral resolution (λ/Δλ)	25 500	25 900	25 800	25 900
SNR @ L_{mean} (per channel)	285	378	344	177

MicroCarb, part of the GHG international constellation for 2021-26 period



- **Launch 2021 is important**
- **We expect**
  - to be in flight with OCO-2 for cross calibration/ validation
  - coordinated operations with OCO-3 and GOSAT-2
  - Play a part in preparation of global stocktake 2023/2028
  - Contribute to preparation of future CO2M (Copernicus)
- **Ready to develop collaboration with other agencies to prepare cross-calibration & cross validation campaigns (cf. MAGIC), and support scientific exchange**

Organization

cea cnrs Institut Pierre Simon Laplace

LMD

LATMOS

THE UNIVERSITY of EDINBURGH

UNIVERSITY OF LEICESTER

cnes

- System design and development
- Satellite design an development
- Instrument specification
- Processing definition
- Mission performances
- Calibration and validation
- Operations

Instrument development qualification and calibration

AIRBUS DEFENCE & SPACE

Satellite Assembly integration and Test

ThalesAlenia Space a Thales / Leonardo company

UK SPACE AGENCY

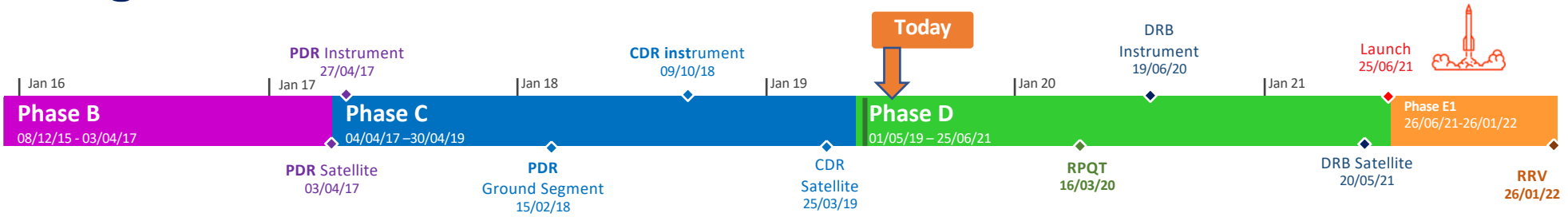
EUMETSAT

Data production, archiving and dissemination

esa European Space Agency

Launch service

Progress



Phase C (detailed design) successfully completed

- Instrument CDR completed (Fall 2018)
- Satellite CDR completed (April 2019)

Now conducting phase D (flight model realization)

- Most of the FM equipment available
- Instrument AIT to be started in the coming weeks
- Platform AIT to be started in the coming weeks

Ground segment

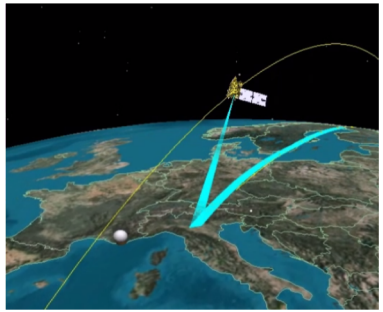
- Wide re-use of existing CNES means and facilities

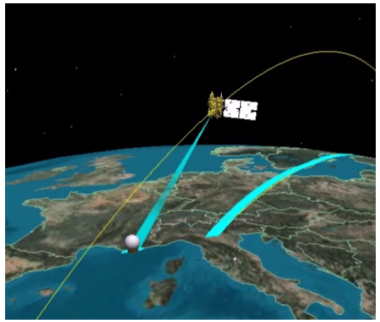
Processing

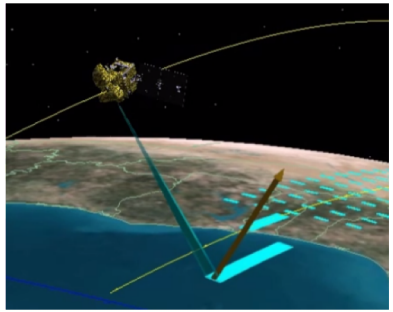
- Specific retrieval tool developped 4A RTIC: includes specific solar radiation model, spectroscopy data base, etc
- Performance evaluation being conducted using OCO-2 data
- Industrial development to be started in the coming weeks

On line with a launch 2nd half of 2021

Multiple Observation modes

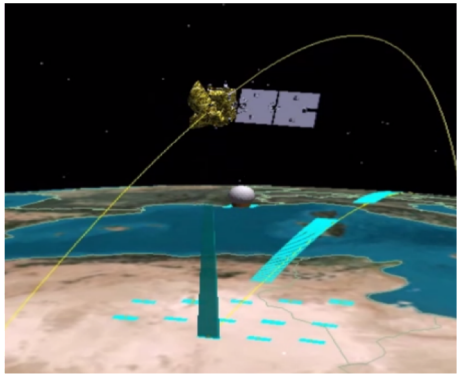






Routine mode

- Nadir, off-nadir (lateral depointing)
- Glint
- Target
- Scan
- WFOV/IFOV= 15



Calibration mode

- Sun pointing
- Moon pointing
- Night pointing over oceans
- Earth limb pointing

Observation modes

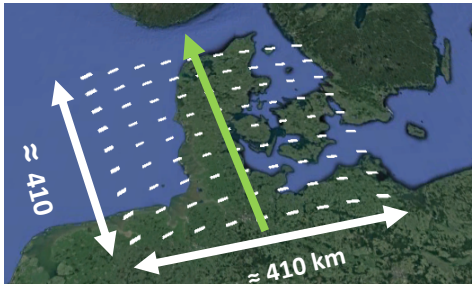
Exploratory mode: City mode

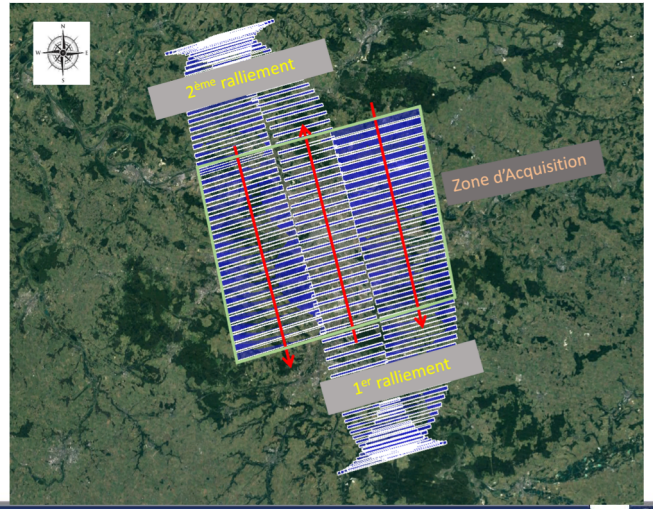
- Typical footprint: 2 km x 2 km
- Typical area surface: 40 km x 40 km
- Obtained by slowing down the satellite scrolling + maneuvers + scan activation + binning tuning (on ground) + integration time tuning
- No data acquisition before / after (satellite maneuver)

Dedicated presentations during IWGGMS-15

- "The potential of the XCO_2 high resolution imagery …" Grégoire Broquet
- "Plume detection and characterization from XCO_2 imagery … " Claude Camy-Peyret

Also applicable at regional scale





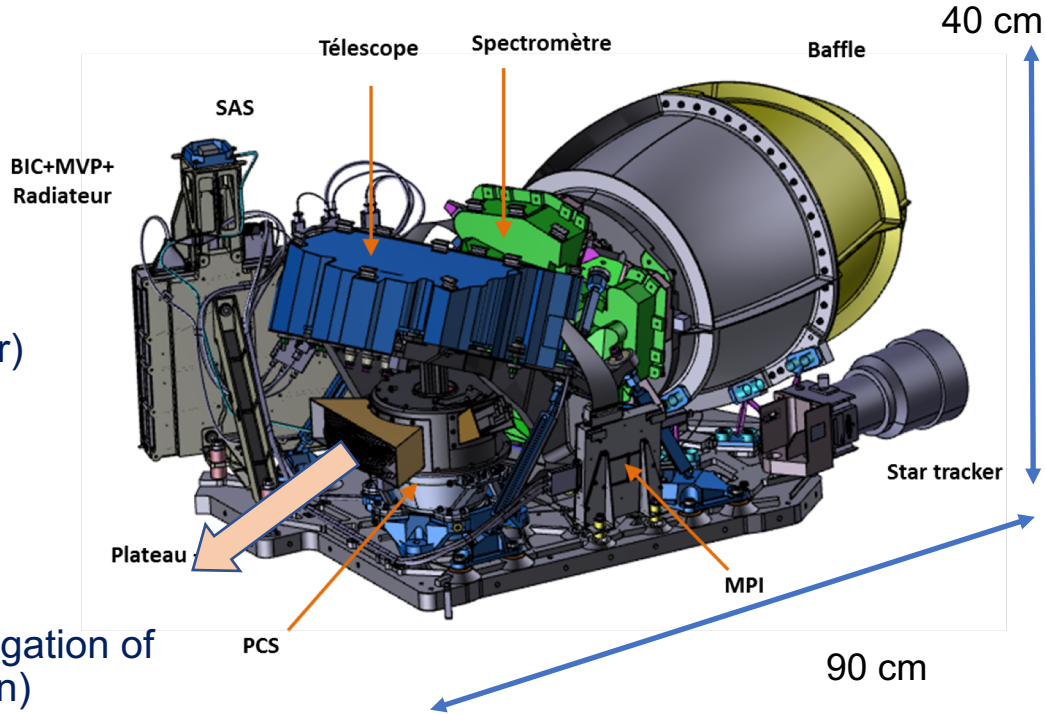
Instrument

Description

- Passive SWIR Spectrometer
- Integrated imager (cloud detection): 0.625 µm

Features

- One unique spectrometer (one grating, one detector)
- On board scan mirror (one axis)
- Passive cooling (150 K)
- Calibration: solar port with diffuser, white lamps
- Polarization scrambler
- Capacity for intermediate acquisition (10 Hz) → mitigation of non uniformity of scenes ALT effects (ISRF distortion)
- No processing aboard
- High stability (geometrical, radiometric and spectral): use of SiC material, accurate thermal control (< 0.1 K), electronics

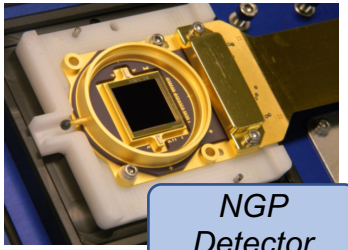


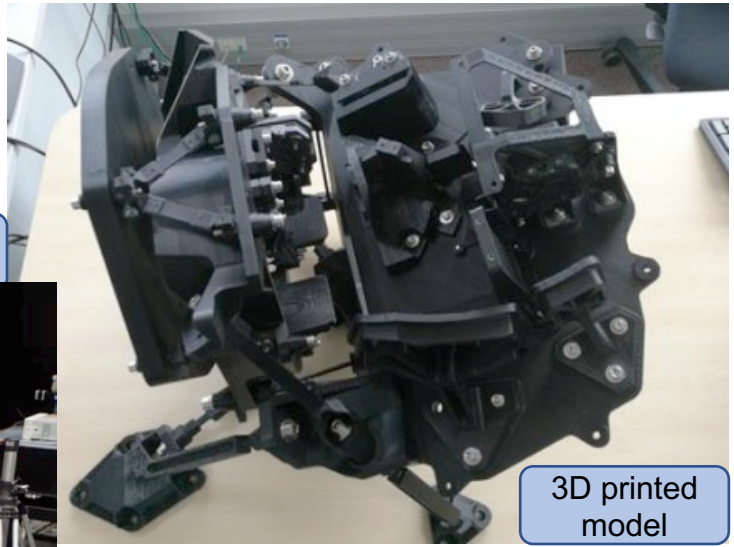
Parameter	Value
Mass	72 kg
Power	< 57 W
Data rate	500 Gbits/day

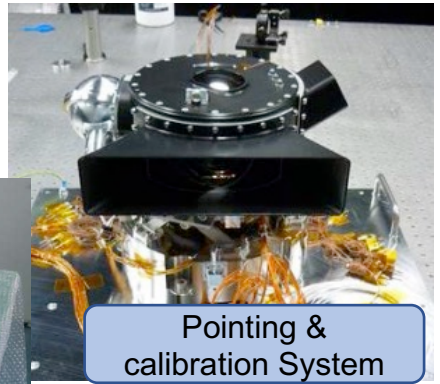
Instrument development status


Baffle


Echelle grating


NGP Detector


3D printed model


Pointing & calibration System

- Assembly and integration to be started end of June 2019
- Followed by environmental testing
- Then full calibration
- Delivery expected June 2020
- Carried out by Airbus DS Toulouse

Instrument calibration. On Ground

Tests performed under thermal vacuum condition

Optical devices

- Tunable laser source
- Wide band source
- Integrating sphere
- Collimator
- Polarizer

Other tests

- Gas cell → characterization in absorption
- **Test with heliostat**
  - ✦ Different air masses
  - ✦ Matador

→
- Acquisition in the 4 bands
- Comparison with EM27
- Detection of defects at instrument or L1 or L2 level

Radiometric performances

- Dark signal: offset and stability
- Non linearity
- Absolute and relative gain
- Verification straylight model
- Verification polarization model

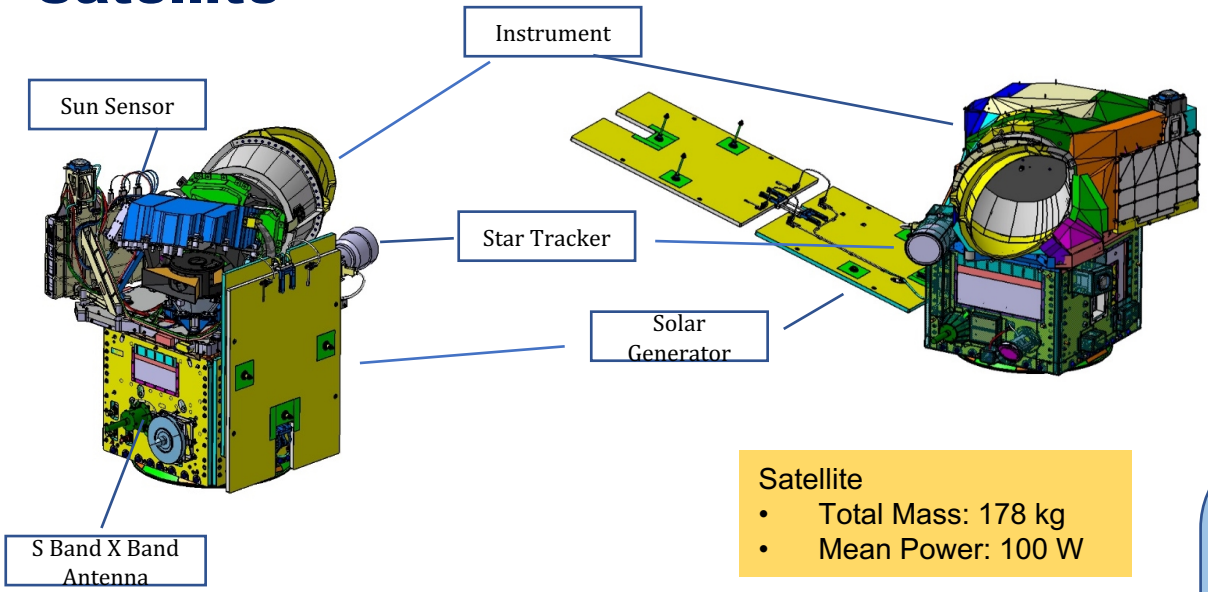
Spectral performances

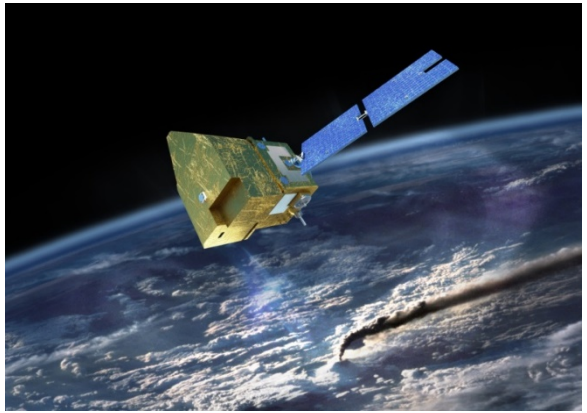
- Dispersion law parameters
- Keystone
- ISRF Shape

Spatial performances

Cross calibration with GOSAT TANSO-FTS-2 (common radiometer: under investigation)

Satellite

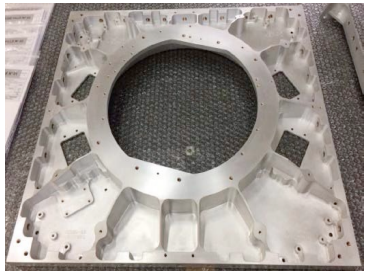
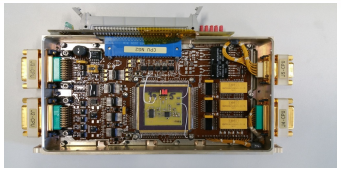
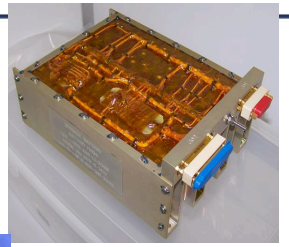




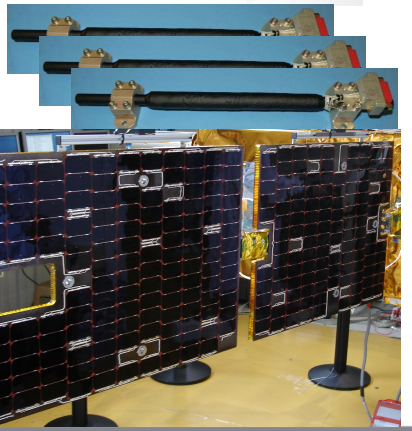
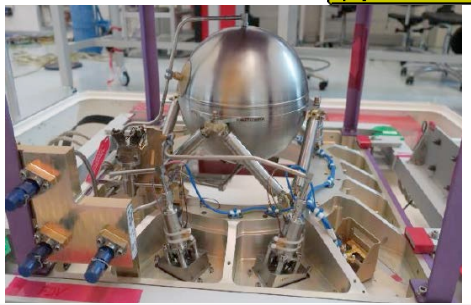
Satellite
- Total Mass: 178 kg
- Mean Power: 100 W

- Enhanced Myriade family
  - *Computer*
  - *LOS*
  - *AOCS (gyroless)*
  - *New SST, TMTC, TMHD*
- Flight proven: used for 19 satellites
- Dimensions 80 cm x 100 cm x 110 cm
- High rate telemetry: 156 Mbits/s
- On board Data storage: 800 Gbits
- Hydrazine propulsion : 55 m/s
- Steerable solar generator

Satellite AIT



- Assembly and Integration to be started July 2019
- Followed by payload integration
- Then environmental testing
- Delivery expected June 2021
- Carried out by Thales Alenia Space (UK)

In orbit calibration and validation

Instrument calibration

- **Closed shutter**
  - Dark signal: offset and stability
- **White lamp**
  - Relative radiometric gain
  - Keystone
- **Sun Pointing**
  - Absolute radiometric gain
  - Reference solar spectrum
  - Dispersion law parameters
- **Moon pointing**
  - Co registration, etc
- **Vicarious campaign**
- **Ground laser pointing**

Data validation

- The following is considered
  - Comparison to TCCON station (+ EM 27)
  - Aircore (balloon flight)
  - Instrument on board aircrafts
  - Comparison to models
  - Cross validation with other projects (OCO-2, OCO-3, GOSAT, GOSAT-2,Tansat, etc)

Data processing

Presentation by Denis Jouglet at IWGGMS-15

Processing tools under development

- Radiative transfer : 4A-OP (by LMD)
- Inversion algorithm: 4A RTIC (optimal estimation)
- Implementation of B4 ongoing
- Spectroscopy data base: based on improved existing GEISA + addition of O_2 @1. 27 µm
- Solar model: based on
  - SOLSPEC (by LATMOS) for the continuum
  - And Toon for solar lines
- Scattering modelization. VLIDORT, SOS

Other products

- SIF, airglow

Validation

- Processing applied to OCO-2 L1 data and comparison to OCO-2 L2
- Step 1: clear sky, nadir: completed
- Step 2: comparison to TCCON , scenes with aerosol , estimation of SIF, glint mode: ongoing
- Results now close to those obtained by ACOS

Data latency

- Products will be available within 48 hours in compliance with CAMS (Copernicus) requirements

MicroCarb main innovations

- ISRF knowledge in heterogeneous scenes
- L1C with refined geolocation, spectral law and polarization impact
- Intra-FOV information (a few channels) gives access to albedo, ice, NDVI, clouds
- Cloud detection: based on imager and intra-FOV pixels
- 1.27 µm band : better assessment of the aerosols (Angström coefficient), less sensitive to spectroscopy errors, same vertical sensitivity to aerosols as WCO2 + SCO2

A complete chain of processing for L1 & L2 (& L3) is now specified

- Most critical parts are prototyped
- Testing under going for 4ARTIC, to come for other parts
- Ground segment development starts next september

Format of products : as similar as possible to OCO-2

- To ease the use of the MicroCarb data by the community

A SIF product will also be computed by a pre-processor

- To be provided by UoL (Hartmut Boesch & Dongxu Yang)

City Mode of MicroCarb

The main priority is the CO_2 natural fluxes

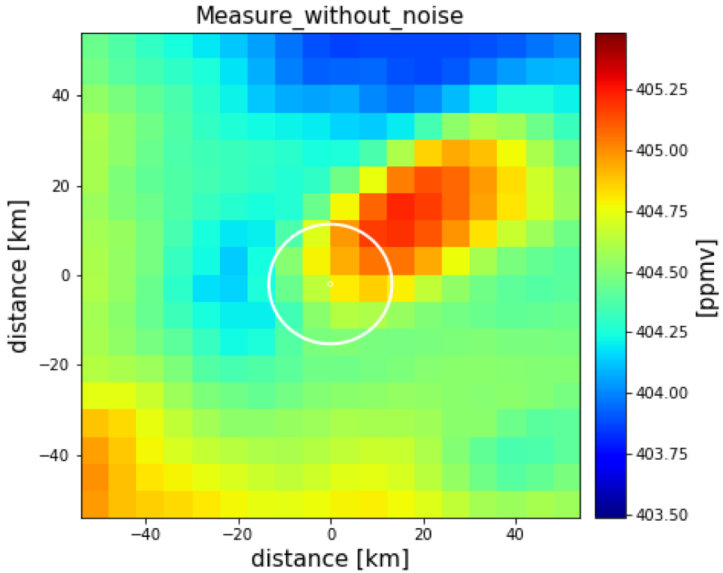
But as a demonstration, a small fraction of the observing time will be devoted to power plants and megacities

- XCO_2 image of ~ 40 km × 40 km
- Individual pixel size 2 km × 2 km (i.e. 20 × 20 pixels)
- Precision ~ 1 ppmv
- Gaussian plume model implemented for point sources (possibly multiple) and cities (surfacic emission)
- Work performed with CNES support within a cooperation of SPASCIA (P. Prunet), LSCE (G. Broquet) and IPSL (C. Camy-Peyret)

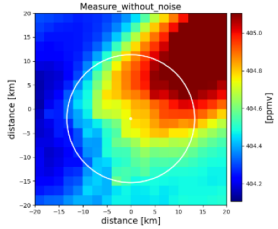
GEO AND MICROCARB MODE COMPARISON

Paris site

GEO mode



MicroCarb mode

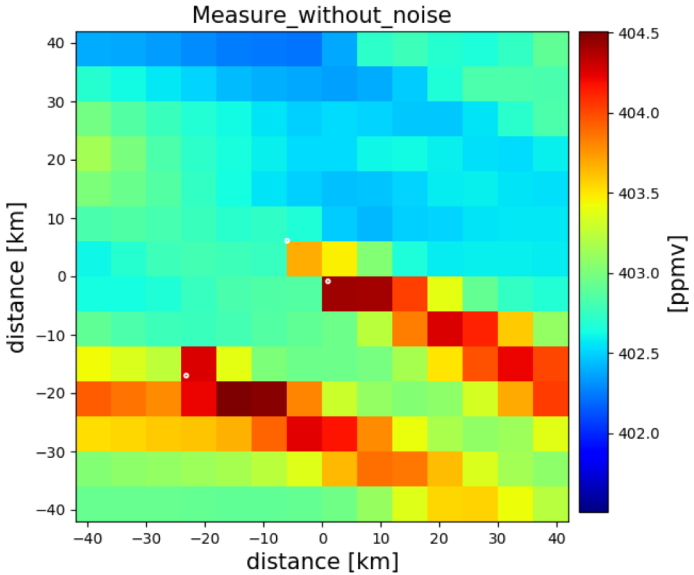


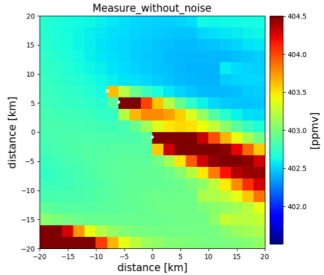
GEO AND MICROCARB MODE COMPARISON

GEO mode

MicroCarb mode

Niederausse m site





Conclusion

- Additional partnership are put in place at European level to place MicroCarb in an European frame and contribute to prepare future operational systems (Copernicus)
- Instrument and satellite AIT to be started soon
- Processors benchmarked and extensively tested using OCO-2 data and give promising results
- MicroCarb is in time and heading for a launch in 2021

Thank you for your attention !