




# FRENCH ACTIVITIES FOR GHG FROM SPACE

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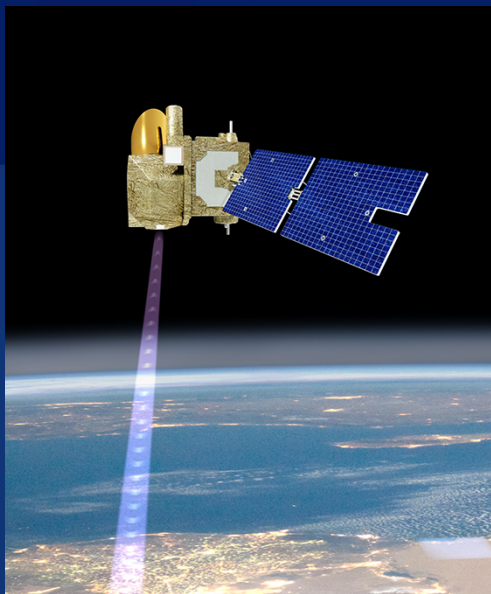
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*With contributions from MERLIN team (Bruno Millet at CNES & Philippe Bousquet at LSCE/IPSL),  
Microcarb team (François Buisson at CNES & François Marie-Bréon at LSCE/IPSL, LMD/IPSL team  
(Cyril Crevoisier)*





# MICROCARB



- Supported by French government
- In collaboration with UKSA



# MICROCARB objectives : Highly Accurate CO<sub>2</sub> observations

MicroCarb aims to make significant progress in answering the following specific questions:

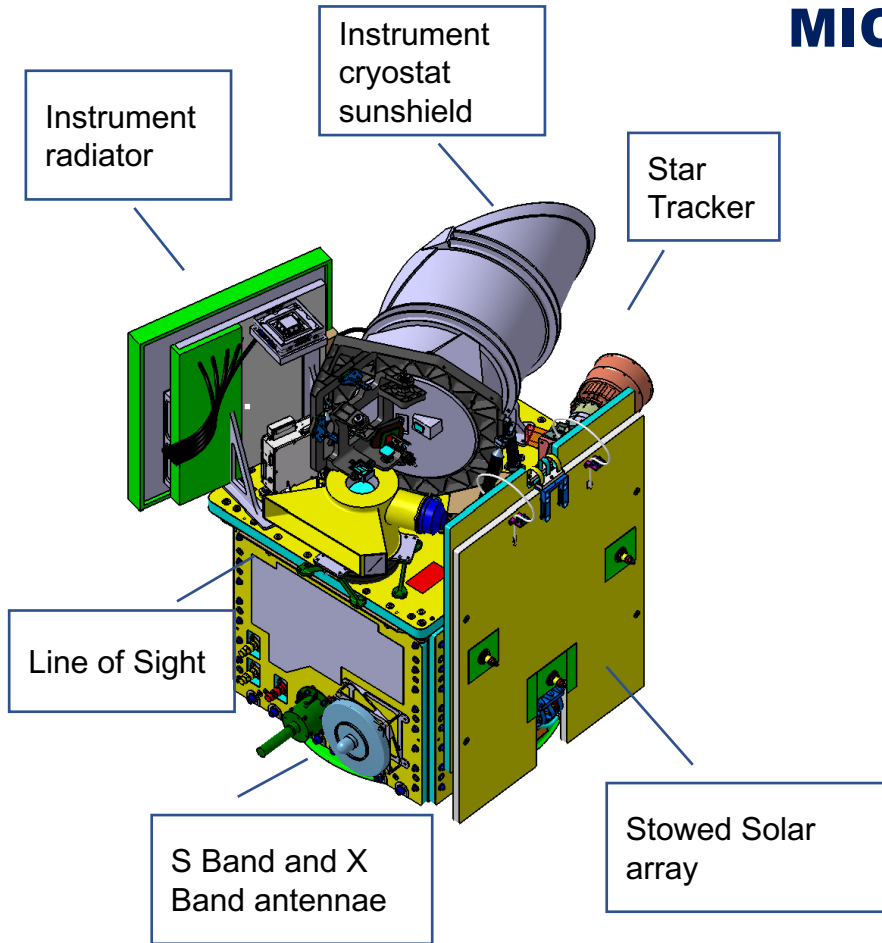
- Where are the main carbon sources and sinks ?      What are the processes that control these fluxes ?
- What is the contribution of land use change to the net land flux?
- How does the Carbon cycle react to large climate perturbations such as El Niño/La Niña events?
- How will the carbon cycle react to climate change?
- *+ Test at highest space resolution for cities emissions estimation*

Accurate measurements are required and are difficult to make:

- Precision < 1 ppm & Bias < 0,1 ppm
- XCO<sub>2</sub> spatial gradients are small (< 10 ppm)
- Regional biases flaw the flux computation



# MICROCARB Satellite description



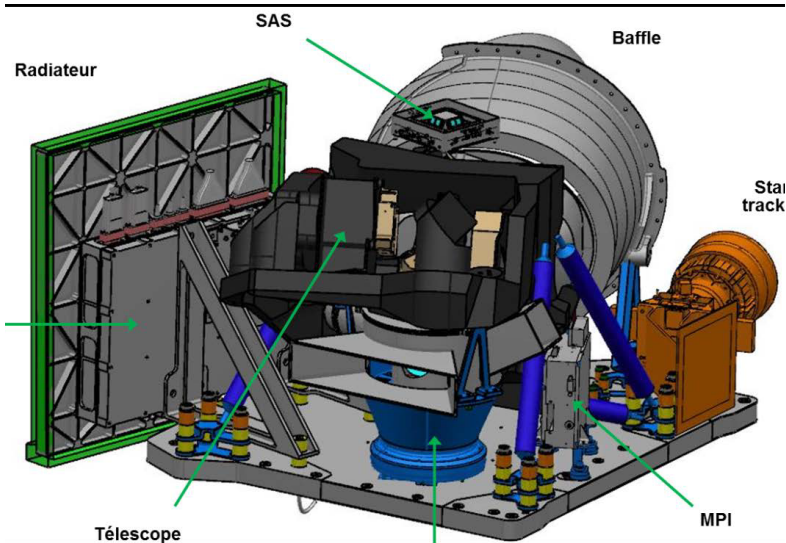
## Myriade family (Microsatellite)

- ❖ Mass : 170 kg
- ❖ Power: 100 W
- ❖ Propulsion: Hydrazine 50m/s
- ❖ Telemetry high rate: 156 Mbits/s

## Orbite

- ❖ SSO – 649 km – 10h30 LTDN or 13h30 LTAN
- ❖ 25 days - 7 days sub-cycle
- ❖ Lifetime : 5 years

# MICROCARB Instrument description



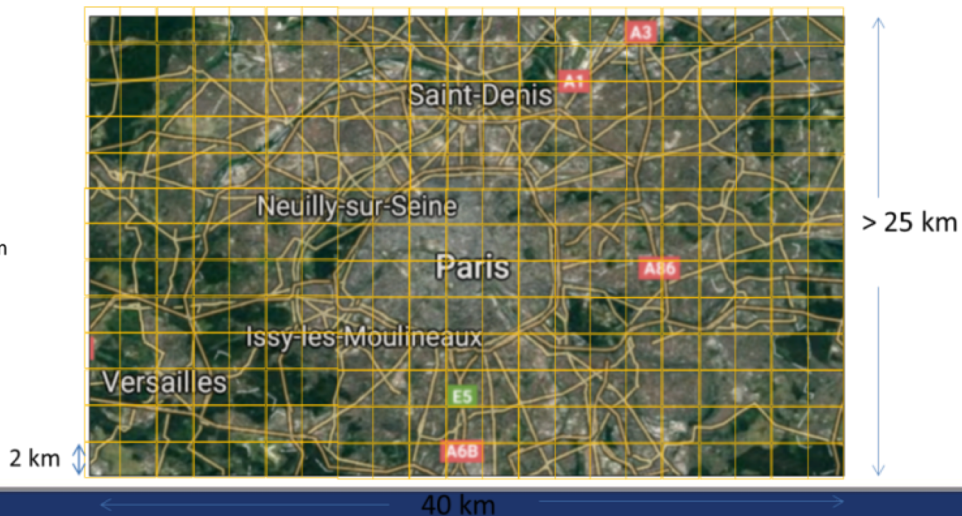
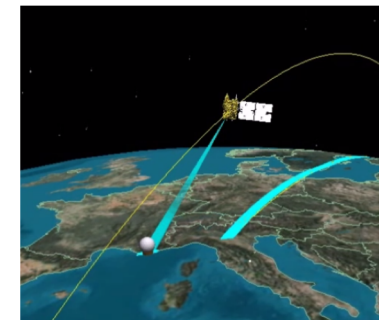
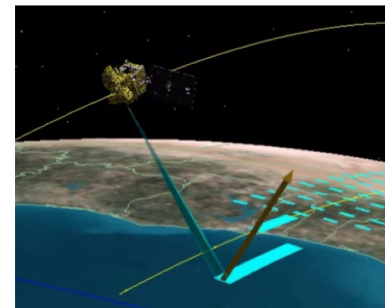
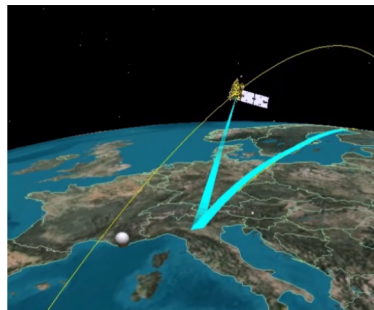
- ❖ Passive spectrometer (echelle grating) in SWIR
- ❖ Unique detector : Sofradir NGP (1000 x 1000 px)
- ❖ Passive cooling: Detector: 140 K; Spectrometer: 220 K
- ❖ Integrated cloud imager
- ❖ Mass: 64 kg (nominal)

Performances géométriques	Value
Swath	13,5 km
Size of elementary sounding point	4,5 x 9 km = 40 km <sup>2</sup>
Number of simultaneous soundings	3
Line of sight agility (scan)	±200 km

Performances spectrales	B1 (O <sub>2</sub> )	B4 (O <sub>2</sub> )	B2(CO <sub>2</sub> )	B3(CO <sub>2</sub> )
Wavelength centrale (nm)	763.5	1273.4	1607.9	2037.1
Bandwith (nm)	10.5	17.6	22.1	28,1
Résolution spectrale ( $\lambda/\Delta\lambda$ )	25 500	25 900	25 800	25 900
SNR @ Lmean (per channel)	285	378	344	177

# MICROCARB : Agility of pointing

- ❖ Nadir above Land
- ❖ Glint above ocean
- ❖ Target mode for calibration ( Sun or TCCON)
- + Exploratory Mode for City above big cities (pixel 2x2 km<sup>2</sup>)



# MICROCARB next steps

EVENT	Date
RCD Instrument	Jun 2018
End of phase C (RCD satellite)	Décembre 2018
Start AIT PF & satellite	Février 2019
Instrument Delivery	Décembre 2019
Flight Acceptance Review (FAR)	Décembre 2020
Launch date	Mars 2021
End of phase E1 (commissioning)	Septembre 2021

+ Delivery of Version 1 of ATBD and preparation of processing chains, of validation activities with scientific laboratories LSCE, IPSL, LMD, LATMOS, and partnership with UK.

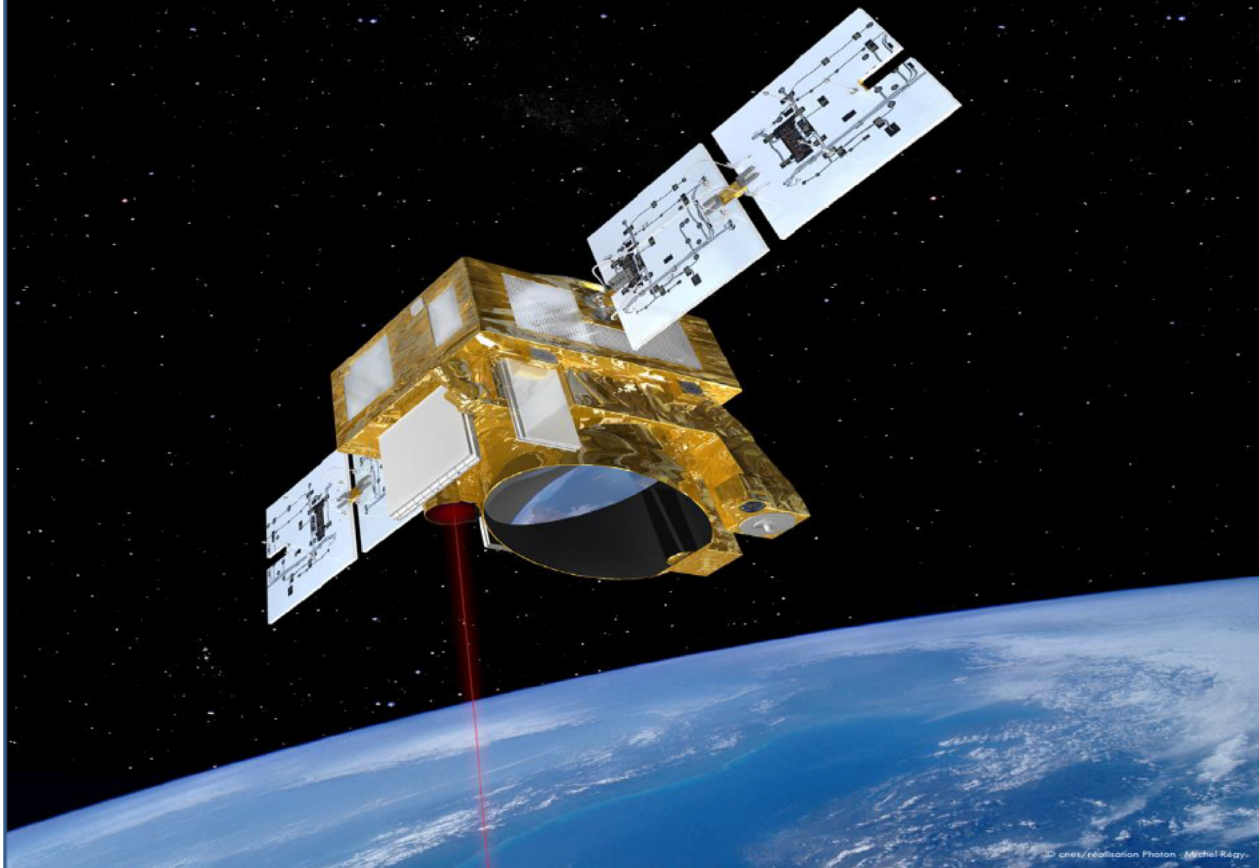
- Scientific PI: Francois Marie BREON, LSCE



*Breadboard exposed for the One planet summit in Paris in décembre 2017.*



# MERLIN, MEthane Remote Sensing Lidar Mission



laboratoire d'Étude du Rayonnement et de la Matière en Astrophysique



Laboratoire Inter-Universitaire des Systèmes Atmosphériques



# Global methane budget 2003-2012 (TgCH<sub>4</sub>/yr)



## Bottom-up

	<b>184 [40%]</b>
	<b>192 [15%]</b>
Rice	35 [10%]
Enteric ferm & manure	100 [20%]
Landfills & waste	57 [20%]
	<b>118 [20%]</b>
Coal	47 [80%]
Gas & oil	71 [10%]
	<b>35 [30%]</b>
	<b>185 [90%]</b>
Fresh waters	99 [100%]
Wild animals	10 [100%]
Wild fires	3 [100%]
Termites	9 [120%]
Geological	60 [50%]
Oceans	3 [100%]
Permafrost	1 [100%]



## Natural wetlands Agriculture & waste



## Oil & gas exploitation



## Biomass & biofuel burning

## Other natural emissions



## Top-down

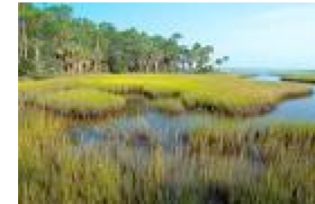
**176 [80%]**

**197 [64%]**

**115 [50%]**

**26 [54%]**

**54 [150%]**



Process-based budget  
(Bottom-up models & inventories)

**714 TgCH<sub>4</sub>/yr [600-853]**

Mean [min max range %]

Atmospheric-based budget  
(Top-down inversions)

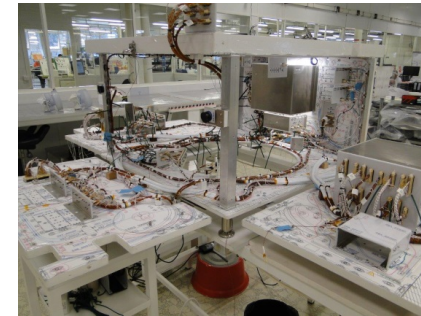
**568 TgCH<sub>4</sub>/yr [539-609]**

*Saunois et al.*

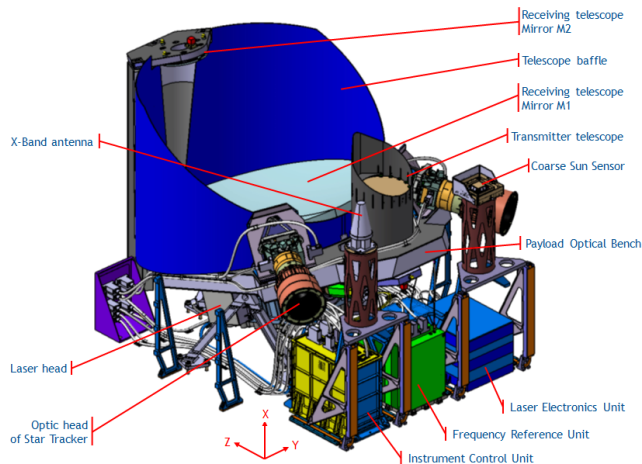
# MERLIN : Measurement concept

Platform: **MYRIADE Evolutions** line of product

Satellite (platform + payload)	
Mass	430 kg
Dimensions	160 cm x 120 cm x 160 cm
Power	500 W



- **Payload: IPDA Laser Instrument:** transmitter based on OPO and Future Laser (FULAS) concept, developed under ESA and DLR contracts



Payload	
Mass	140 kg
Power	150 W
On-line $\lambda_{on}$	1645.552 nm
Off-line $\lambda_{off}$	1645.846 nm
Pulse energy	9 mJ
Pulse length	20 ns
Repetition rate	20 Hz (double pulse)
Telescope diameter	690 mm



# MERLIN objectives

To deliver :

- XCH4 : Column-weighted dry-air mixing ratios of CH<sub>4</sub>, along the satellite sub-track
- Associated Random and systematic errors
- Monthly Maps of XCH4 and associated errors

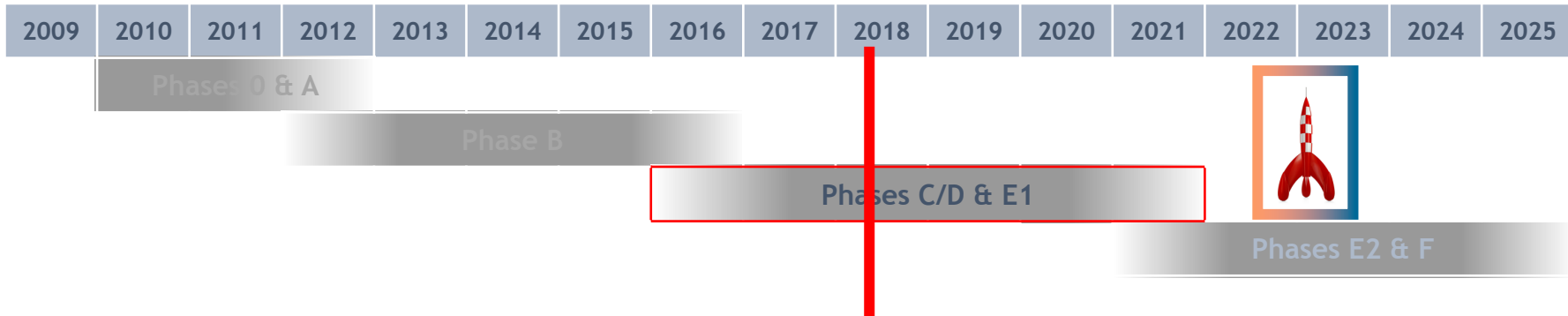
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## MERLIN System Requirements:

Random error:	< 27 ppb
Systematic error:	< 3,7 ppb
Horizontal sampling accumulation:	50 km (can be shorter depending on SNR)

MERLIN shall be the first active mission in space dedicated to GHG

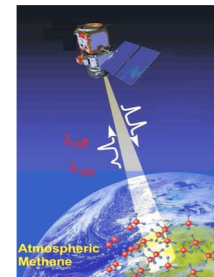
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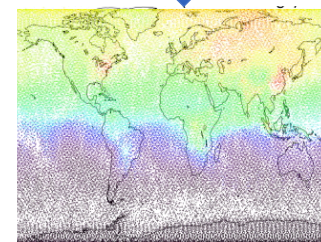
# Interest of active mission for CH<sub>4</sub>..

- with lower biases (<3ppb) than passive instruments (auto-calibrated)
- day and night ( no sunlight needed)
- At all latitudes (including high latitudes)
- For all seasons

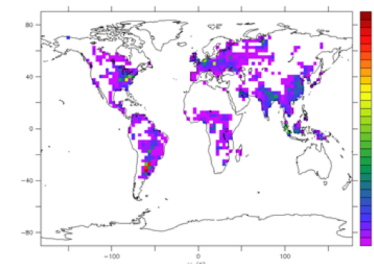
It will open a new dimension of the space observation of greenhouse gases from space.



Columns



Fluxes





# GHG observations with IASI (TIR) on METOP

## From 2006 to now... and up to potentially 2035 with IASI-NG



IASI is a FTIR spectrometer which was developed by CNES for Eumetsat and the programme include 3 instruments onboard METOP-A (2006), B (2012) and C (2018)..

=> sensibility in the high troposphere...

It will be followed by IASI NG programme for 15 more years..



Cyril Crevoisier, R. Armante, V. Capelle, F. Capalbo, A. Chédin, L. Crépeau, N. Meilhac, J. Pernin, N. A. Scott

<http://ara.abct.lmd.polytechnique.fr>

### IASI-New Generation: improvement on

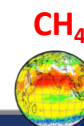
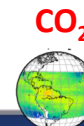
#### Carbon dioxide (CO<sub>2</sub>)

IASI-NG will enable the use of SW channels (4.3.µm), giving access to a lower part of the atmosphere, with a much improved precision.

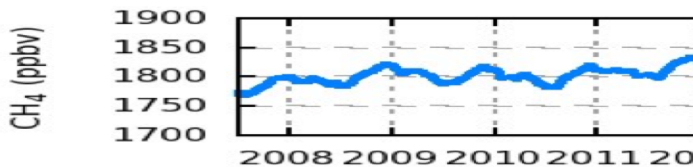
Spectral bands for IASI-NG	Noise	Improvement of the precision
15 µm	IASI/2	30 %
4.3 µm		0 %
15 + 4.3 µm		45 %

#### Methane (CH<sub>4</sub>)

Less interferences with other gases and better noise will improve the precision of the retrievals.



- $\text{CH}_4 + \text{CO}_2$  mid-tropospheric columns from Metop-A + Metop-B (Crevoisier et al., in rev).



- 2 production modes :

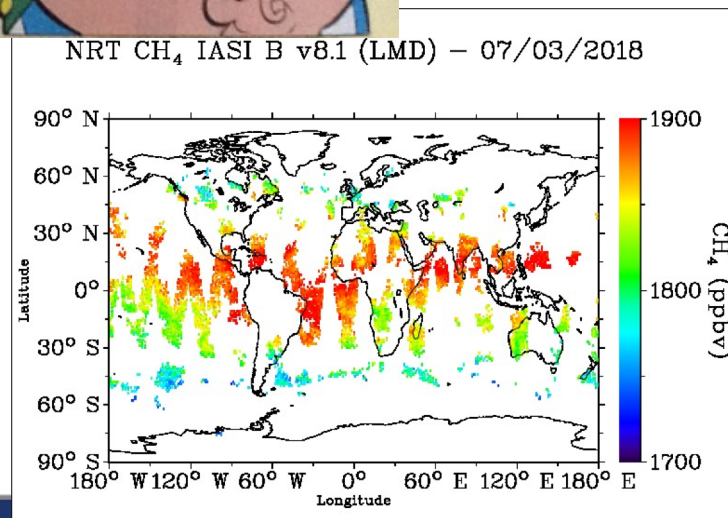
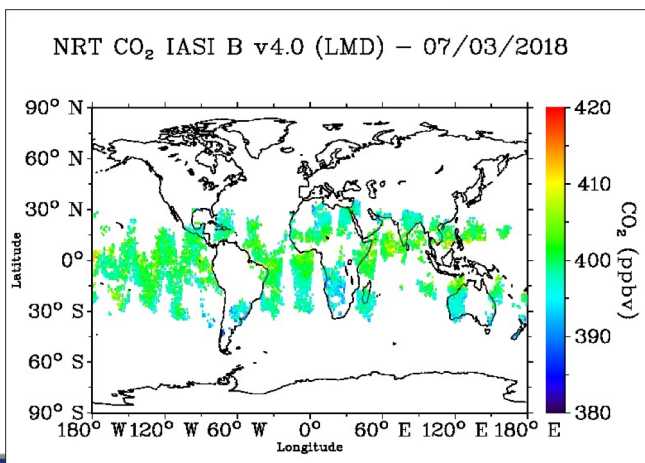
## 1. Near real-time(J+1)

→ to CAMS/Copernicus Services since 2017

→ For  $\text{CH}_4$  &  $\text{CO}_2$  assimilation by IERS and analyses.

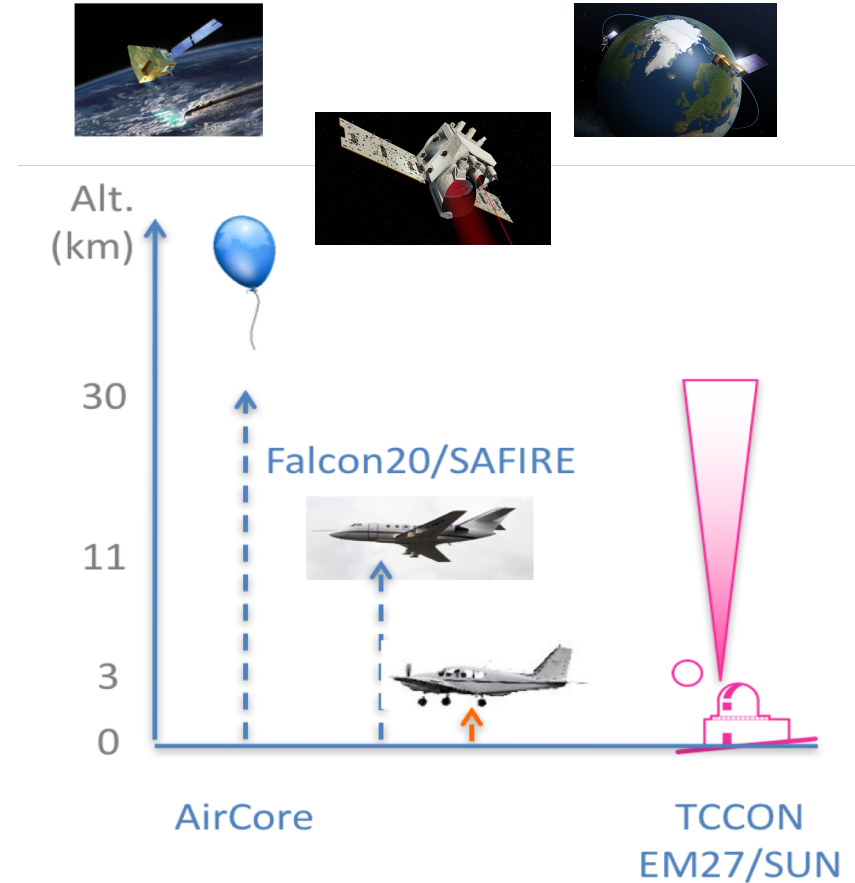


Change Service (C3S) GHG (CH<sub>4</sub>)



# GHG validation campaigns , preparation work (2018-2021)

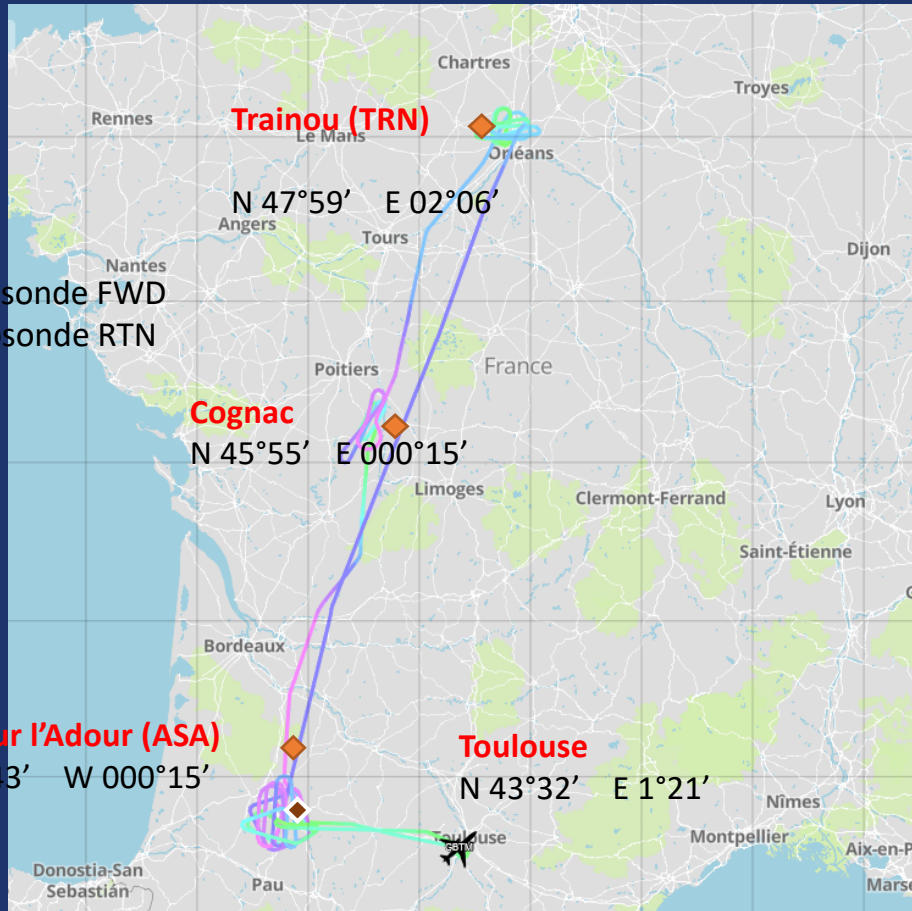
- **Instrumentation :**
  - On aircraft : SAFIRE Falcon20: Picarro, dropsondes and granulometry.
  - On balloon : AirCore under meteo balloons (at ASA and Trainou)
  - On ground : TCCON at Trainou.+ EM27/SUN (COCCON) from LSCE, CNES and LERMA/KIT., CRIS Interferometer from LOA. Mini Lidar for H2O/T at (P. Chazette)
- **The CoMet campaign: 21 May – 2 June 2018 for the French part in collaboration with german part with HALO (with CHARM-F) flying above F20 for 11-15km part of the profile.**
- **Next campaigns:** from CoMet to MAGIC ..
  - Test of pixel heterogeneity, spectroscopie/Rad. Transfer with full column characterization.
  - Air sur Adour as a “super site”: EM27/SUN + Picarro (ICOS) + monthly launches of meteo balloons (AirCore, LOAC) + Rds.
  - Other regions: high latitudes (Kiruna + Siberia with YAK campaigns), tropics (new balloon site).





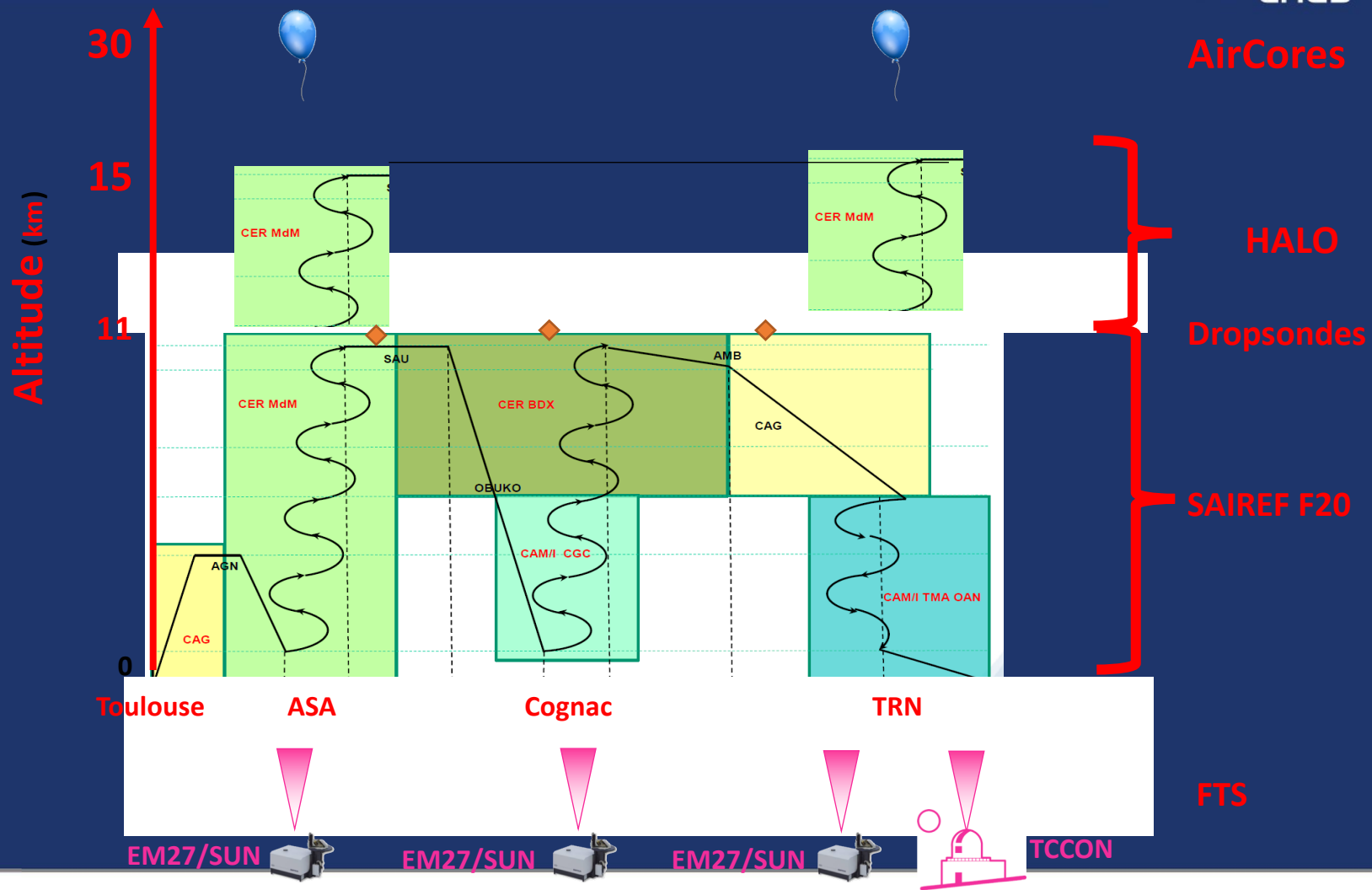
# Example of campaign in France : preCoMet campaign (2017)

## Flight plans



Forward: Toulouse → TRN (3h15)

# Exemple of campaign in France : The CoMet campaign – draft







# CNES Partnerships are essentials to build together..

- ❖ Collaboration with **NASA** (OCO 2 & GGeoCarb teams) for Microcarb
- ❖ Collaboration with GOSAT 1 & 2/**JAXA-NIES** for GHG validation and calibration (with IASI, IASI NG, MERLIN, Microcarb)
- ❖ Collaboration with **UKSA** for Microcarb and **DLR** for MERLIN
- ❖ Strong support for the development of a sentinel 7 dedicated to CO2 in Copernicus (**ESA**).
- ❖ Discussions with **Eumetsat, European Commission and ECMWF** to contribute to Carbone Services
- ❖ Strong interest to develop synergies with chinese programm (**CNSA, CSA..**) on GHG...

## THANKS !