CENTRE NATIONAL D'ÉTUDES SPATIALES

DLR

MERLIN Mission Status

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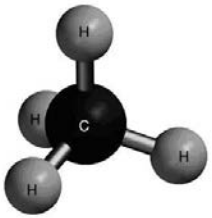
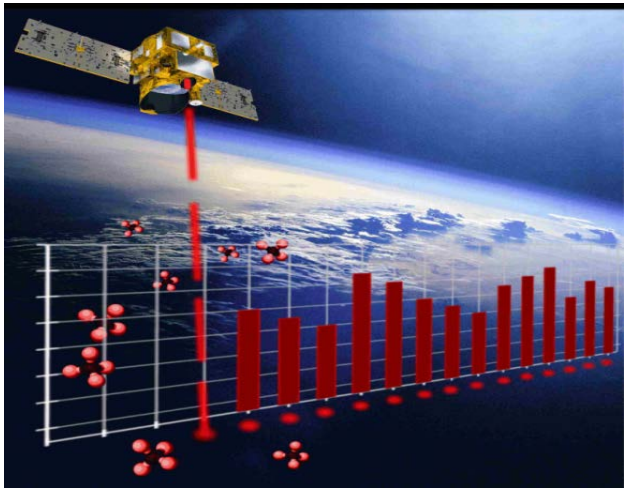
Context

- MERLIN is a LIDAR satellite dedicated to the observation of the spatial and temporal gradients of **atmospheric methane (CH_4) columns**

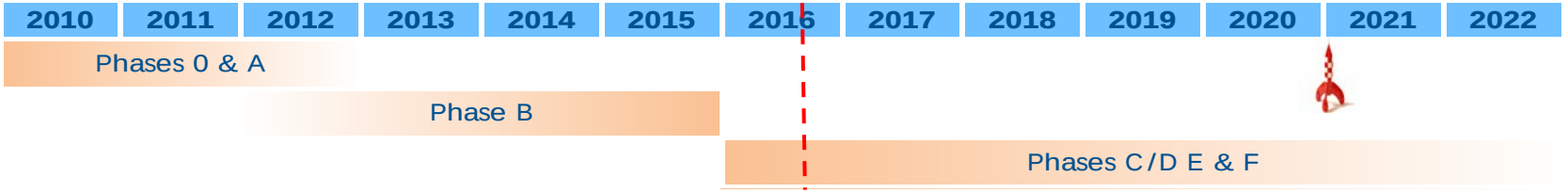


- MERLIN is a space-borne precursor for a CO_2-lidar mission in space



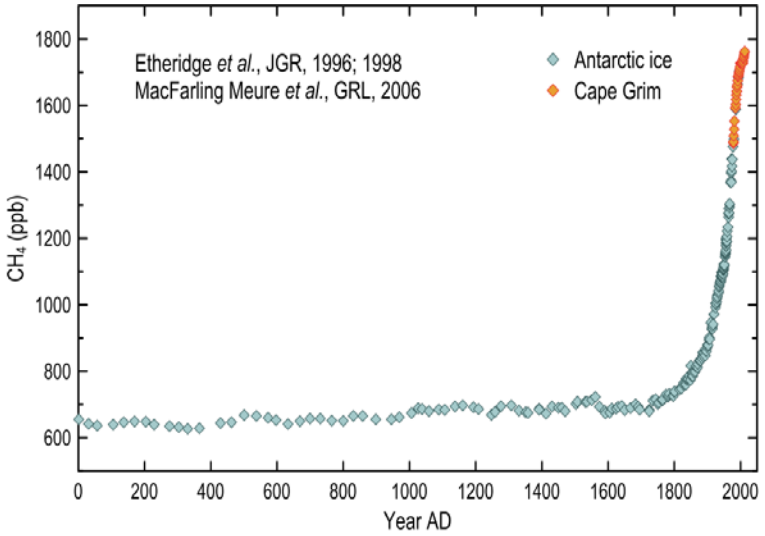
- MERLIN is a cooperation between France and Germany space agencies:
  - CNES in charge of platform, system, launcher, and part of ground segment
  - DLR in charge of payload, and part of ground segment

- Planning:

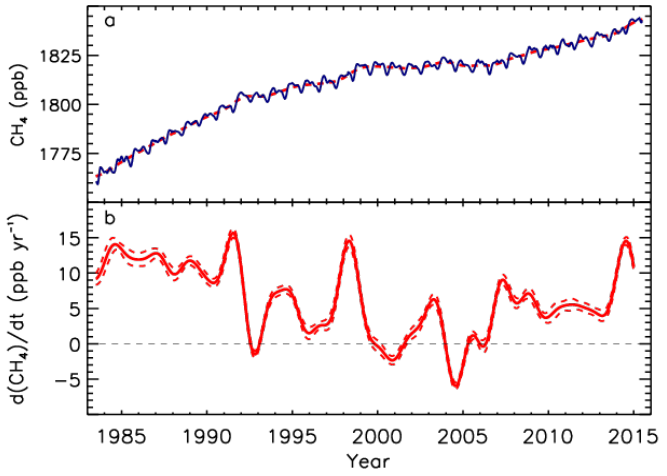


Why Methane ?

- Atmospheric Increase by 150%, from 722 ppb (1750) to 1840 ppb (2015)
- Responsible for >20% of increase in radiative forcing since 1750 (GWP100=28xCO2)
- Contributes to water vapor production in the stratosphere
- Contributes to O3 production in the troposphere
- Lifetime of CH4 is 8-10 years, good target for climate change mitigation
- Present and future CH4 emissions are highly uncertain
- Recent atmospheric variations are puzzling

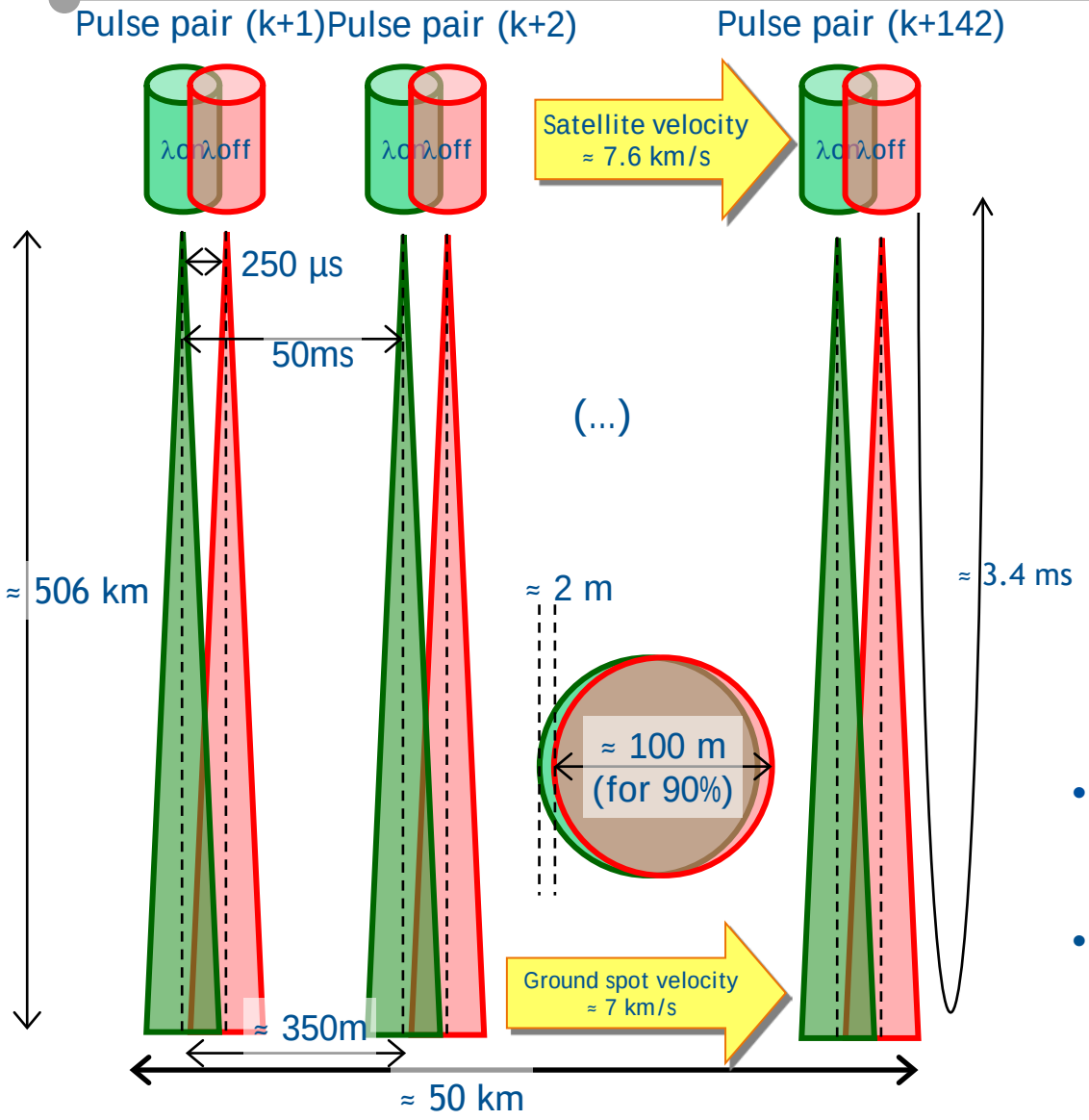


Source: IPCC AR5



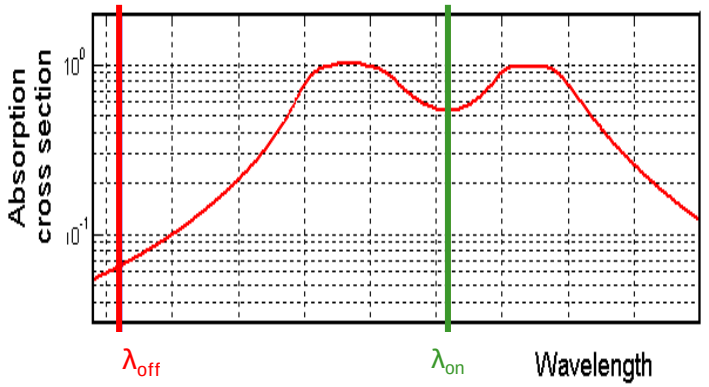
Source NOAA

IPDA-Lidar: New Measurement Concept



- **Integrated Path Differential Absorption (IPDA) lidar**

λ_{on}: 1645.552 nm = 6076.988 cm-1
λ_{off}: 1645.828 nm = 6075.970 cm-1



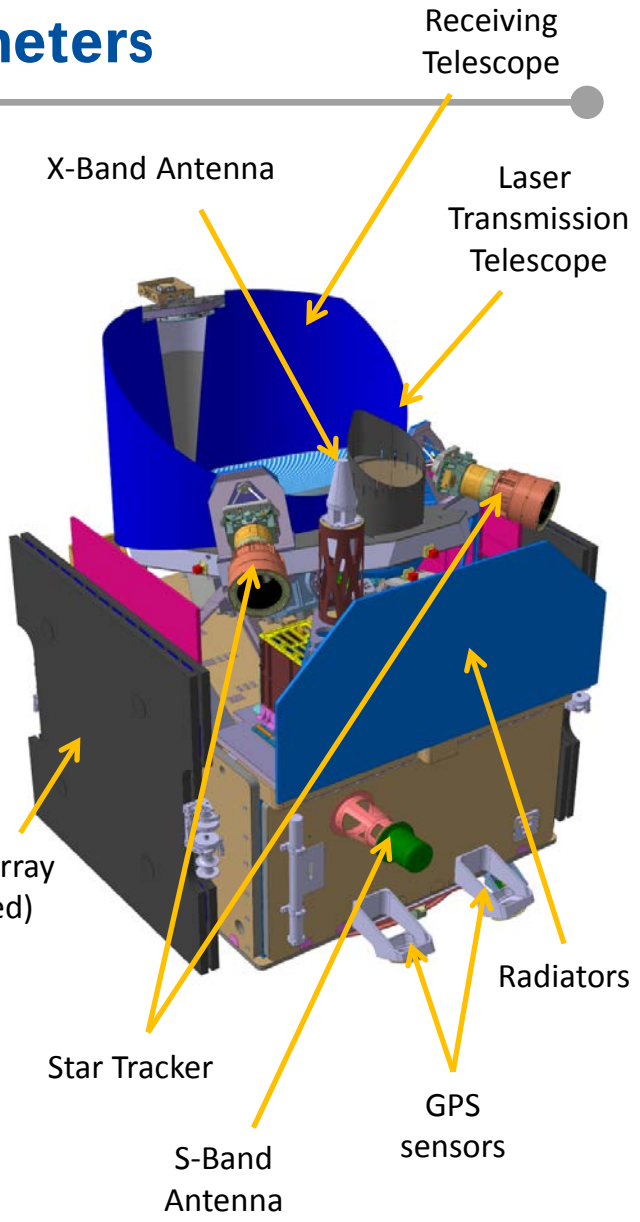
- **acquisition**: all over the orbit, without interruption (20Hz)
- **averaging** of the data along track on 50 km for SNR purpose

MERLIN satellite main parameters

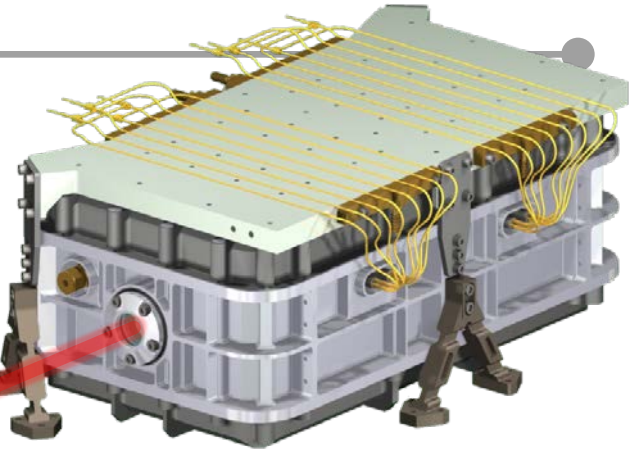
Satellite platform:	MYRIADE Evolutions
• Satellite mass:	400 kg
• Payload mass allocation:	119 kg
• Satellite power:	> 400 W
• Payload power allocation:	150 W
• Satellite GPS:	2 sensors
• Satellite star tracker:	2 opt. Heads

Payload:	Methane IPDA LIDAR
• CH4 absorption line:	1.645 µm
• Laser emitter type:	Nd:YAG pumped OPO
• OPO pulse energy:	9 mJ
• Laser pulse repetition frequency PRF:	20 Hz
• Receiving telescope size:	69 cm
• Detector:	APD pin diode

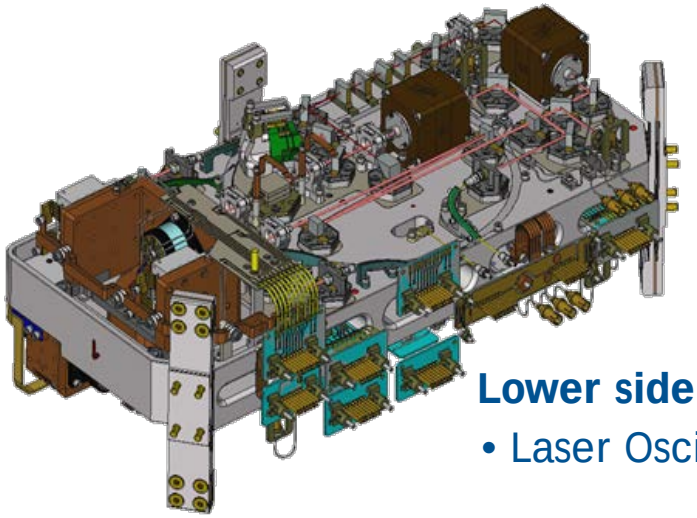
Orbit:	Sun synchr. polar LEO
• LTAN:	06:00h or 18:00h
• Height:	approx. 500 km



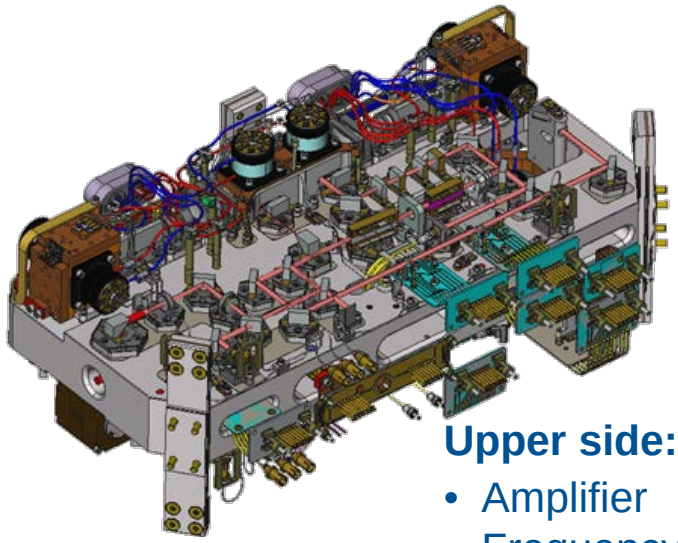
Laser Development: Future Laser qualification model FULAS



- ESA – DLR cooperation
- Airbus DS GmbH & Fraunhofer ILT Aachen
- Generic laser source for future LIDAR missions
- >100 individual optical elements
- High stability (Operational pointing < ±10 µrad)
- "Clean" design: glue-free (bolted and soldered) mounting (→ Optomech Project, DLR / Fraunhofer ILT)

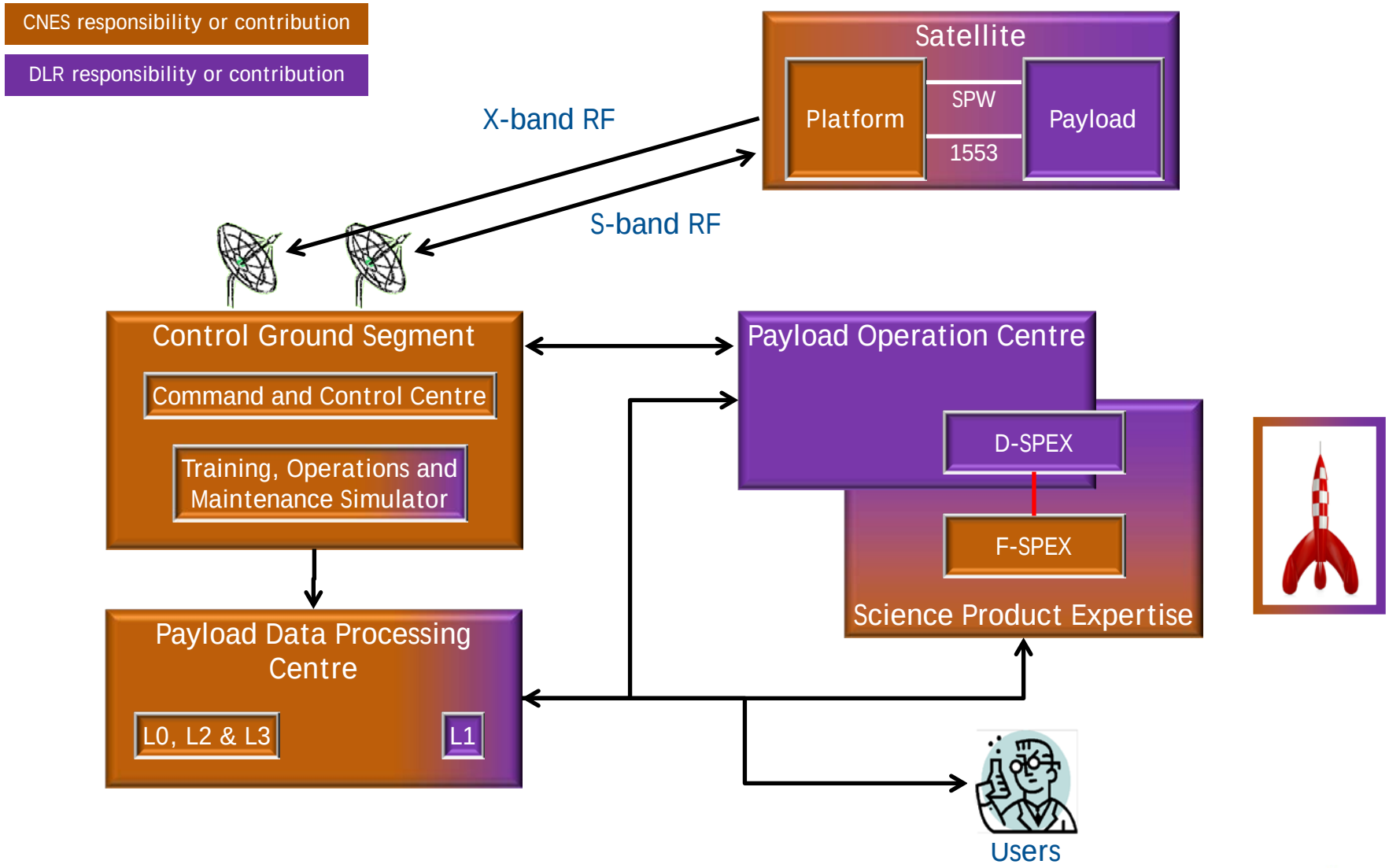


Lower side:
- Laser Oscillator

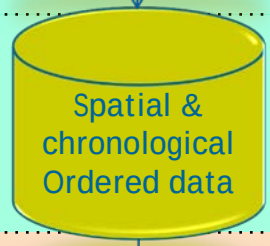
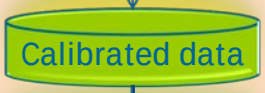
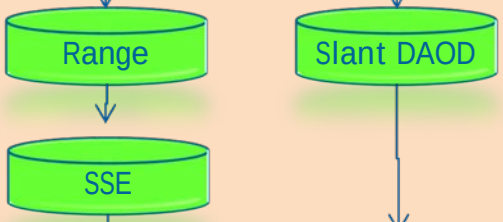
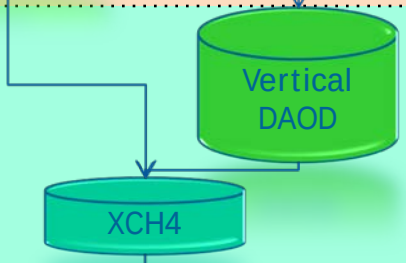
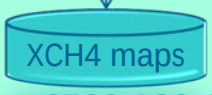


Upper side:
- Amplifier
- Frequency conversion

MERLIN – System Architecture



MERLIN mission products (1/2)

	Products	Content
-		**Raw data** from satellite as downloaded on earth terminals
Level 0 Data		Raw Lidar signal intensity per range-gate Laser pulse energy information Wavelength information Time stamp scientific data
Level 1a Product		Measurement intensity (λon & λoff) corrected by the calibration factors based on the instrument characteristics (non linearity of the detector,…)
Level 1b Product		Range R Slant DAOD along the line of sight Quality index attribution to the range and the DAOD Surface Scattering Elevation
Level 2 Product		DAOD: Differential Atmospheric Optical Depth (shot by shot & average) XCH4: Column-Weighted Dry-air Mixing Ratio of Methane (elementary & average) Weighting function (elementary & average) Quality index
Level 3 Product		XCH4 maps: Temporal & Spatial interpolation of individual XCH4

MERLIN mission products (2/2)

- Level 4 products:
  - methane surface fluxes at various temporal and spatial scales, obtained through assimilation of level 2 products in transport model.
  - not part of the official MERLIN mission but provided by scientists at various scientific research centers.
- secondary products:
  - MERLIN can provide information about the surface:
    - topography,
    - estimates of the vegetation height and occasionally on the vertical structure,
    - lidar retro-reflectance
  - and the atmosphere:
    - cloud boundaries, including cloud base for small to moderate cloud optical thickness.

Expected performances

- MERLIN mission requirements (for a reference value of 1780 ppb):

MERLIN System Requirements:	
Random error:	**< 22 ppb**
Systematic error:	**< 3 ppb**
Horizontal sampling accumulation:	**50 km**
Objectives:	• Seasonal and annual budgets on country scale • Resolves country scale gradients

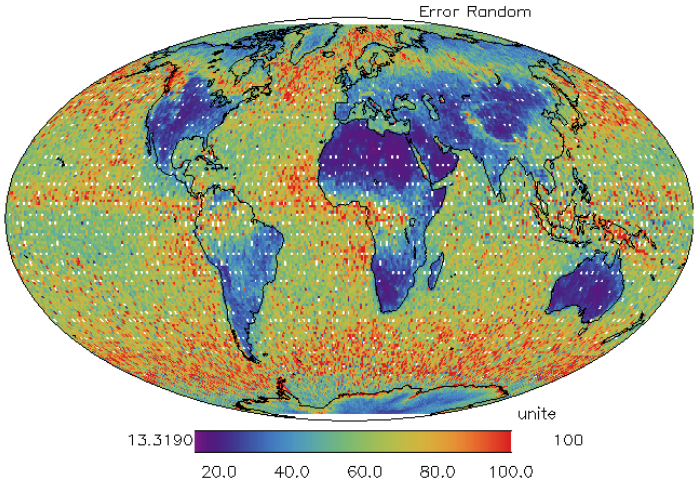
- random error: high frequency, uncorrelated errors
- systematic error: slowly varying component, (e.g. orbital variations, or scene dependent errors).

The very low level of systematic error aims at avoiding geographical biases in the XCH4 fields that could lead to uncertainties in fluxes.

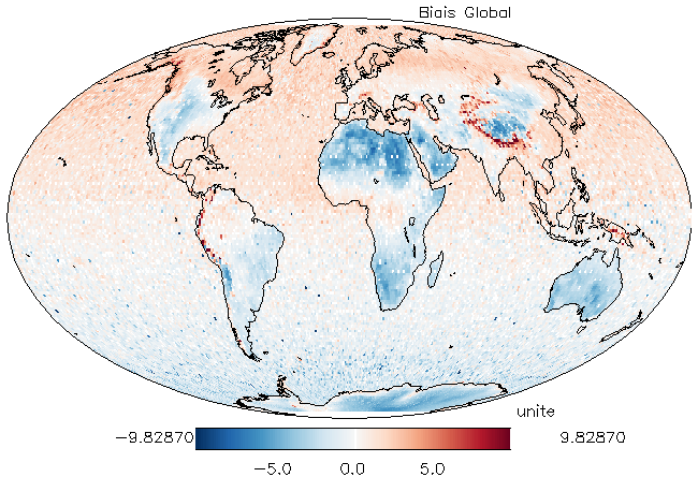
Estimating Impact in Terms of Flux Improvement

- Level 2 performances (random and systematic errors) can be converted into methane flux errors using an inversion of atmospheric transport and chemistry linking atmospheric columns to surface fluxes (level 4)
- To do so the previous analysis on performances is used to produce error maps:

Random error



Systematic error

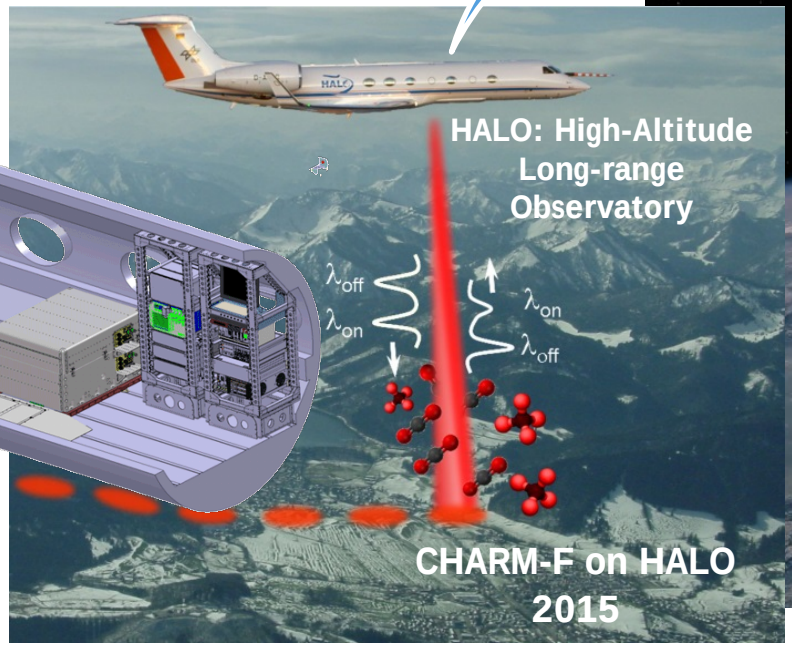


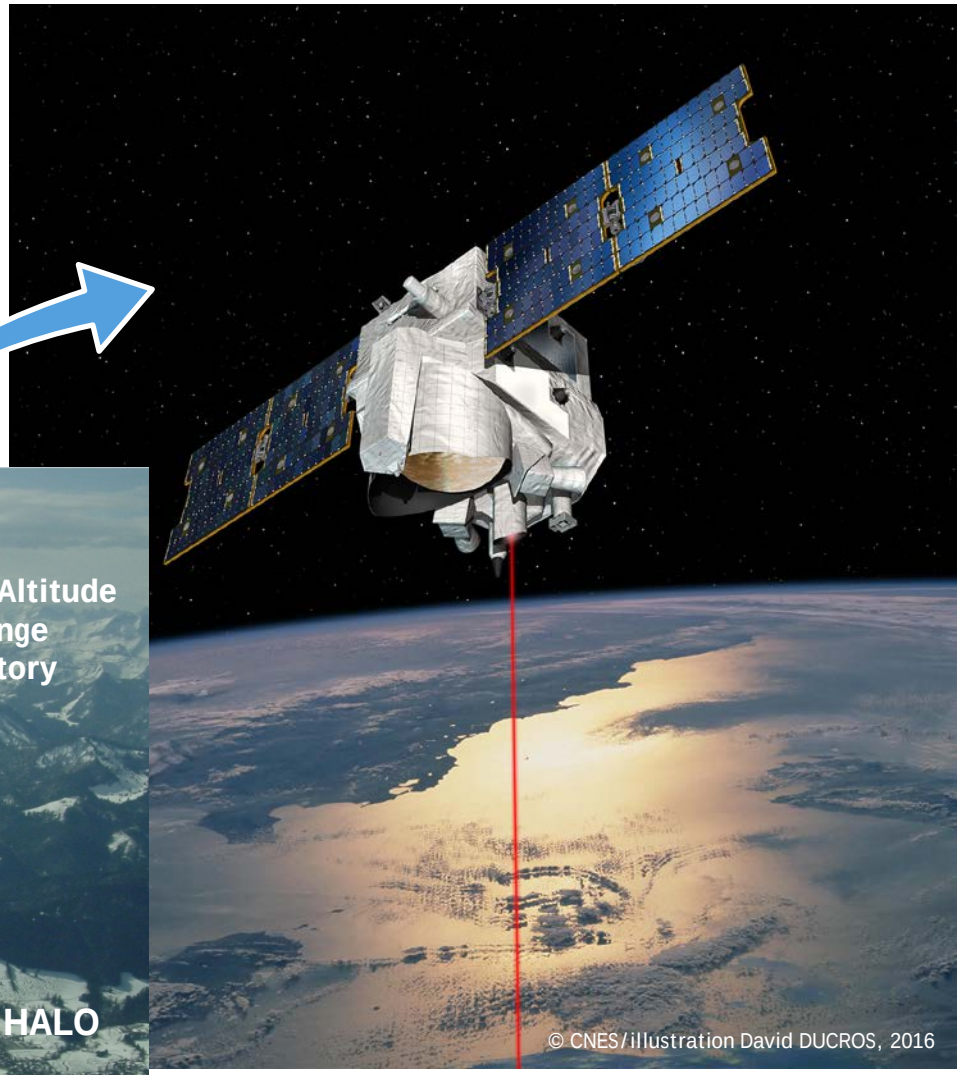
- These maps serves as inputs to compute flux error reductions (on-going work)
- The originality of the work for MERLIN is to account for both random and systematic errors
- The outcome of this work will be to define MERLIN objectives in terms of methane flux resolution and not only in terms of atmospheric concentrations

CHARM-F – an Airborne MERLIN Demonstrator

Core Instrument for MERLIN Validation

HALO performance: 15.5 km altitude, 9000 km range, 3000 kg payload





Conclusions

- MERLIN is a challenging, but well-balanced mission
- MERLIN will implement state of the art of space segment design and ground processing architecture to reach the limit of achievable performances for systematic errors
- **The last word by users:** "The comparatively low systematic error and the year-round global coverage of MERLIN promise to overcome the main limitations of space-borne methane measurements up to this point, providing us with unprecedented knowledge of the sources and sinks of methane worldwide."
- Expected launch in the 2020/2021 timeframe, ~3 years of mission duration