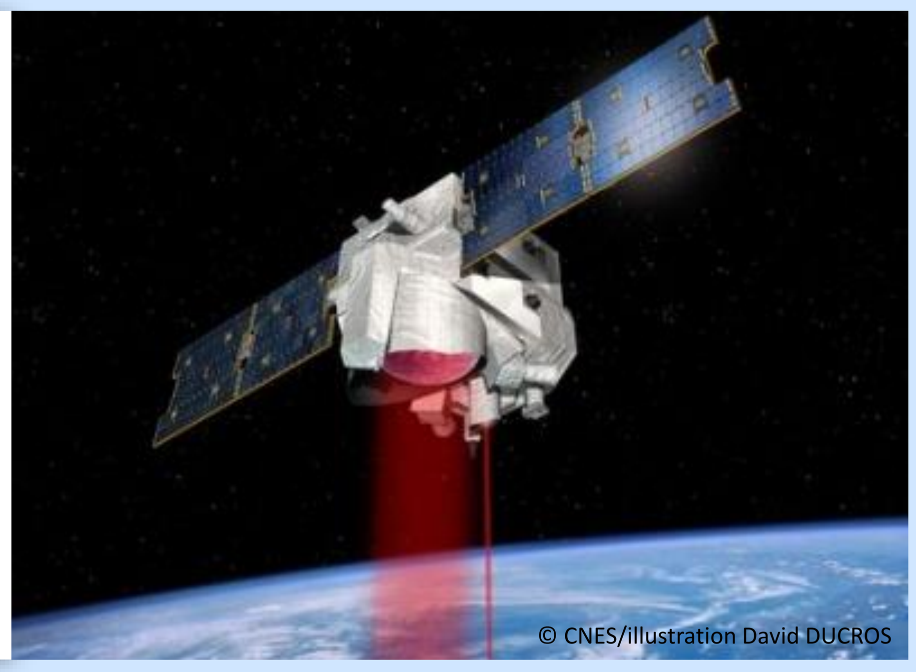
MERLIN – Measuring methane with lidar from space

Sabrina Zechlau[1,2], Dietrich G. Feist[2], Gerhard Ehret[2], Philippe Bousquet[3]

[1]Meteorological Institute, Ludwig-Maximilians-Universität München, Munich, Germany
[2]German Aerospace Center DLR Oberpfaffenhofen, Oberpfaffenhofen, Germany
[3]Laboratory for Sciences of Climate and Environment, Saint-Aubin, France

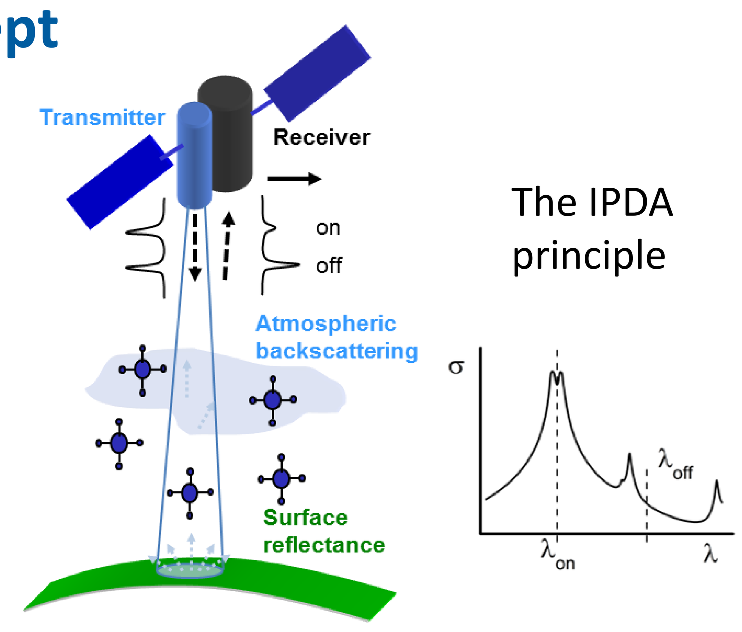
The MERLIN mission

- MERLIN (Methane Remote Sensing Lidar Mission) is a French-German
- Measures spatial and temporal gradients of atmospheric CH_4 columns with lidar and unprecedented accuracy
- Main data product will be column-weighted dry-air mixing ratios of CH4 (XCH4)
- Advantages:
  - **Active remote sensing** system measures during day and night, all seasons (→ helps closing the observational gap in the Arctic)
  - **Small footprint** enables measurements also between clouds and trough thin clouds (→ advantage for observation in the tropics)
  - **High accuracy** coverage of the **entire globe** including the polar regions and measurements of methane over water possible
- MERLIN data will be used in inverse modelling for improving methane **fluxes**.



The MERLIN measurement concept

- Detection of column-integrated dry-air volume mixing of CH_4 (XCH_4) by using Integrated Path Differential Absorption (IPDA) lidar
  - laser footprint: 100 m
  - along track averaging: 10-50 km
  - random error: 18 ppb
  - systematic error: 1.8 ppb



The IPDA principle

measured quantity

$$XGHG = \frac{DAOD}{IWF} = \frac{\frac{1}{2}\cdot \ln\left[\frac{P_{off}\cdot E_{on}}{P_{on}\cdot E_{off}}\right]}{\int_{p=0}^{P_{sfc}} WF_{GHG}(p)\,dp}$$

needs input: T, p, humidity, spectroscopic data

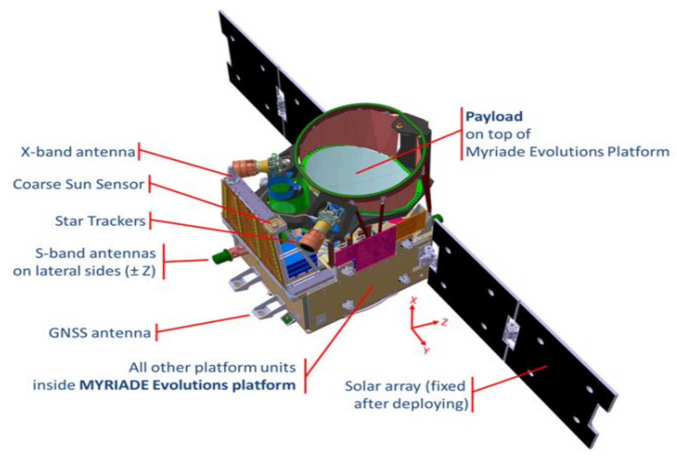
$P_{on,\,off}$: Measured power
$E_{on,\,off}$: Transmitted laser energy

DAOD: Differential Absorption Optical Depth
IWF: Integrated weighting function

- Mean measurement precision of MERLIN data (with a temporal and spatial resolution of one month and 50x50 km[2])
  → land: 1,2 %   → water: 1,7 %   snow/ice: → 2,1 %

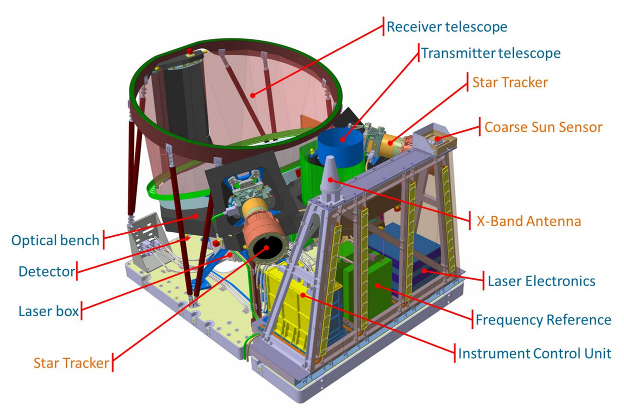
The MERLIN instrument and platform

Satellite platform:	**MYRIADE Evolution**
• 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



The MERLIN satellite. Image credit: Airbus D&S.

Payload:	**Methane IPDA LIDAR**
• XCH4 absorption line:	1.645 nm
• 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:	InGaAs APD



The IPDA-Lidar instrument with all subsystems integrated. Image credit: Airbus D&S.

Mission overview

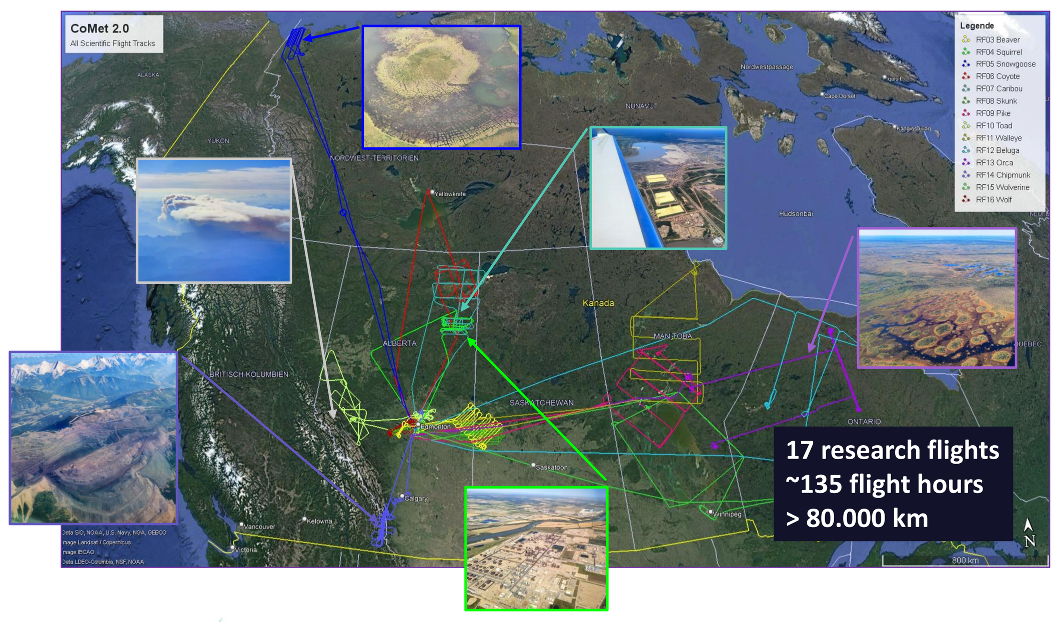
- Satellite is developed and will be operated by both countries in joint partnership
- Germany contributes the payload, a lidar system for CH_4 column density measurements
- France contributes its new satellite platform MYRIADE Evolutions and will operate the satellite
- The MERLIN mission is currently in phase D (system assembly and integration)
- Expected launch in early 2029 for a duration of > 3 years
- Low polar sun-synchronous orbit, height ~ 500km
- LTAN: 6h/18h, repeat cycle: 28 days

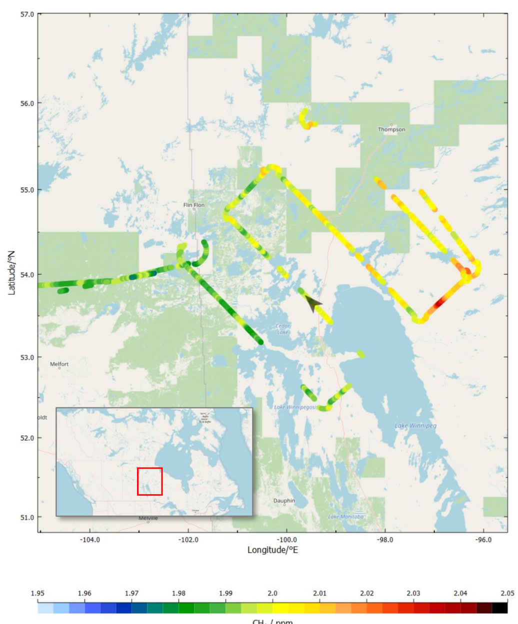
CHARM-F: Airborne demonstrator for validation

- Methodology and performance was proved by CHARM-F instrument during flight campaigns
- Proven during the CoMet (onboard HALO) and MAGIC (onboard the French ATR42) campaigns.
- The latest MERLIN preparation campaign took place in Canada in summer of 2022 using the German HALO aircraft: CoMet 2.0 Arctic (CoMet = $\mathbf{CO_2}$ and **Meth**ane).
- Focus: detection of natural (wetlands, permafrost regions) and anthropogenic (oil and gas industry) methane emissions.

CHARM-F onboard HALO

HALO, the German research aircraft



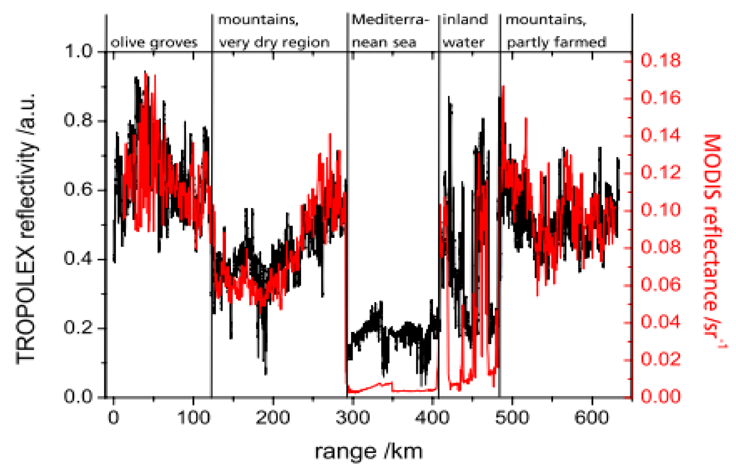


Flight tracks of all research flights performed during CoMet 2.0 Arctic. During 17 research flights as much as 135 flight hours or > 80.000 km of flight route were successfully completed.

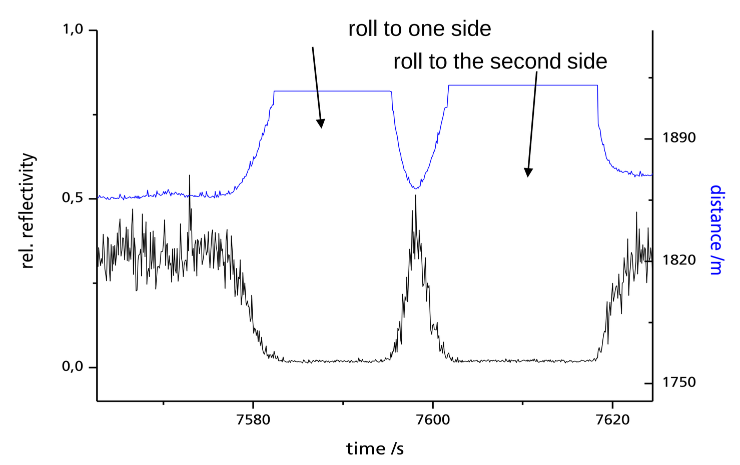
Preliminary measurement example from CoMet 2.0 Arctic: XCH_4 recorded with the CHARM-F instrument on a flight to the wetlands north of Lake Winnipeg (date: 2022/08/26). Small gradients in the CH_4 distribution are clearly visible and will be subject to detailed analysis.

Challenge: Measuring methane over water bodies

- 20 - 31% of global methane emissions are from wetlands and are a key unknown in the global methane budget
- XCH_4 measurements from space by detecting methane over water
- Only possible with active remote sensing



- Variability of Lidar reflectivity during test flight over Spain (black) and MODIS reflectance along flight track (red) with 1,6 µm wave length and 500 m pixel resolution. (Ehret et al., Bousquet et al., , Amediek, 2009)



- Black: Lidar measurement over water
- Blue: line-of-sight distance to ocean surface, achieved trough different roll angle of airplane
- reflectance depending on the angle of incidence. (Amediek, 2009)

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Did you know that CoMet is a campaign series, taking place every ~ 4 years? For more details about CoMet 2.0 – Arctic checkout https://comet2arctic.de/ or scan the QR-code on the left.

Find out more about the MERLIN mission and the measuring principals and visit our website on https://merlin-methane.space/ or scan the QR-code on the left.

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