MERLIN

Methane Remote Lidar Mission

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TCCON Annual Meeting
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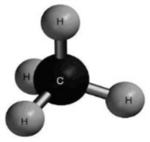
Context

- **Franco-German contribution** to the climate conference **COP-15** at Copenhagen (8.-15.12.2009)
- Visible contribution to the **climate focus** by accurate measurements of the greenhouse **gas methane (CH4)**



- **Joint partnership**: Germany develops the **CH_4-Lidar**, France provides the satellite-bus

Challenge

- **First** orbital climate mission using an **active lidar** instrument
- „Mini-Class" laser transmitter (**Nd:YAG-laser pumped OPO**) for a mission live time of 3 years

Planning

- Begin 2010
- Phase C/D since 2016
- Launch >2023

MERLIN Atmospheric Methane Lidar Mission

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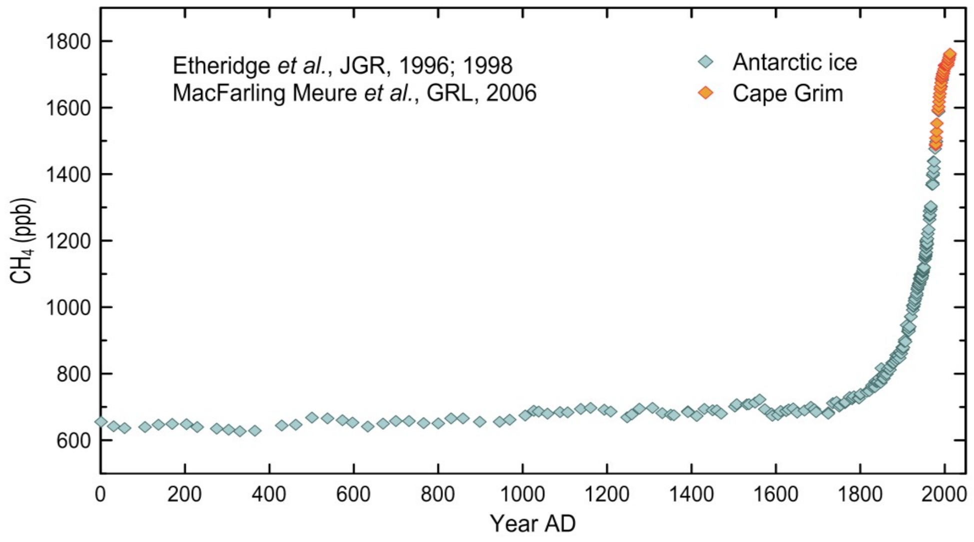
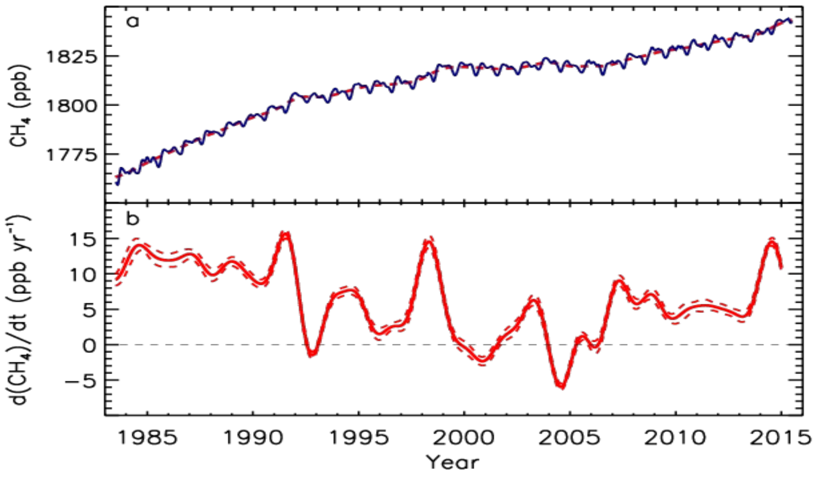
Why Methane ?

- 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 uncer**tain
- Recent atmospheric **variations are puzzling**



Source: IPCC AR5



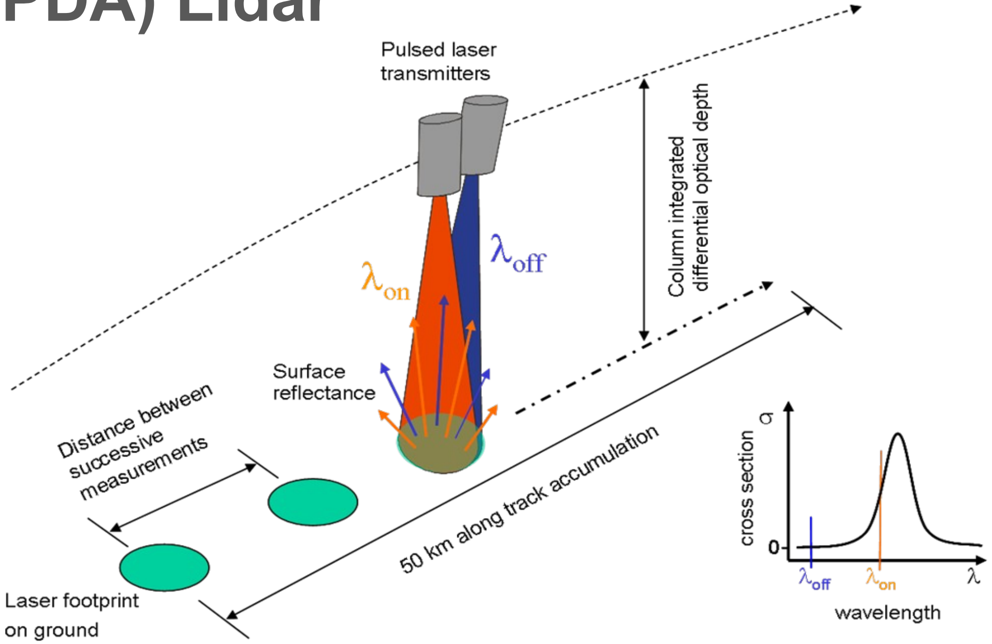
Source NOAA

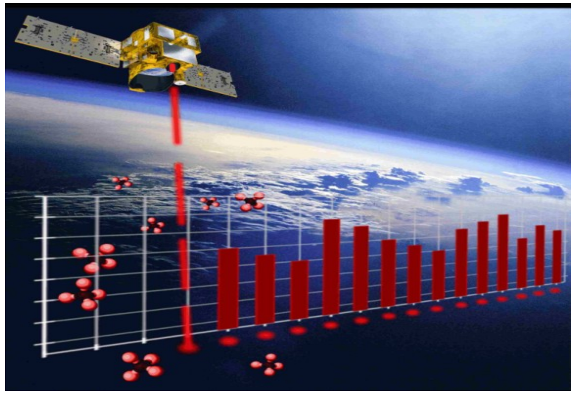
Methode: Integrated-Path Differential-Absorption (IPDA) Lidar

MERLIN approach

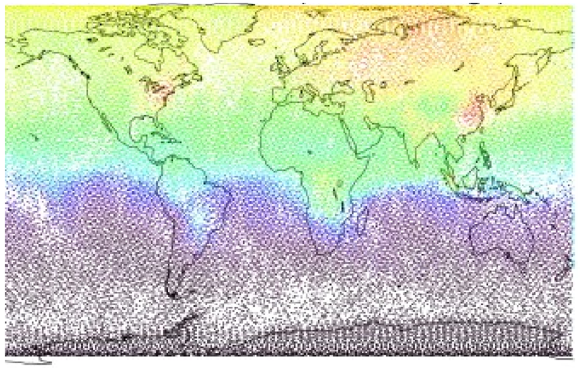
Pulsed spectrally narrow-band laser transmitter with one on-line und on off-line wavelength

Ehret et al., Appl. Phys. B, 2008

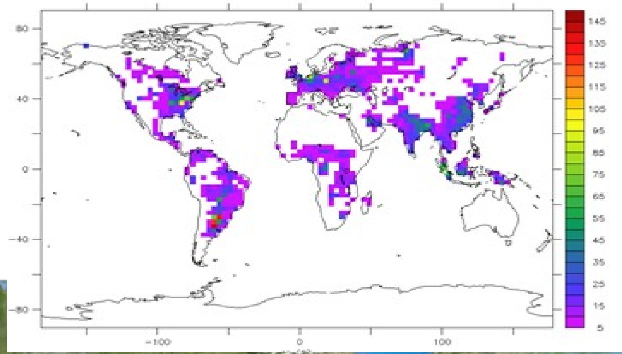




Xgas



Emissions



Why MERLIN ?
As an active RS instrument based on a differential measurement method, MERLIN will deliver **data day and night** with **lower biases (< 0.2 %)** than current, existing and planned space instruments

MERLIN will provide atmospheric methane columns at **all latitudes**, allowing to monitor in particular **tropical** and **Arctic** regions

MERLIN is a **demonstrator of GHG Lidar** measurements from **SPACE**. It will open a **new dimension** of space observations of the Earth. An active RS instrument will serve as a **reference system** in space of a GHG constellation (**COP-21, Copernicus**)

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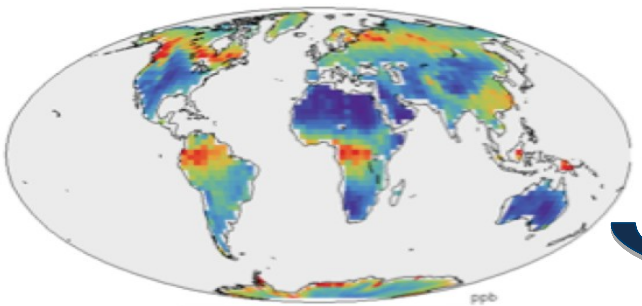
Performance Simulation: XCH4-Flux Error Reduction due to MERLIN

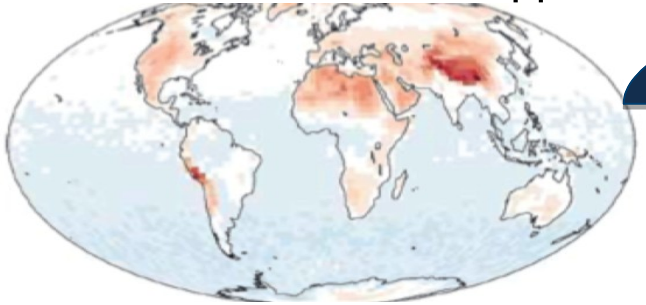
MERLIN data (L2)

Methane fluxes (L4)

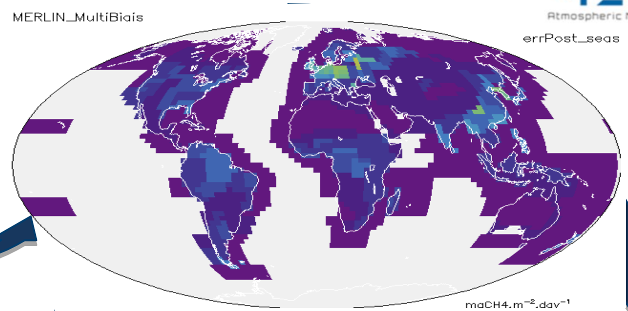
GHG simulator Inversion of atmospheric transport



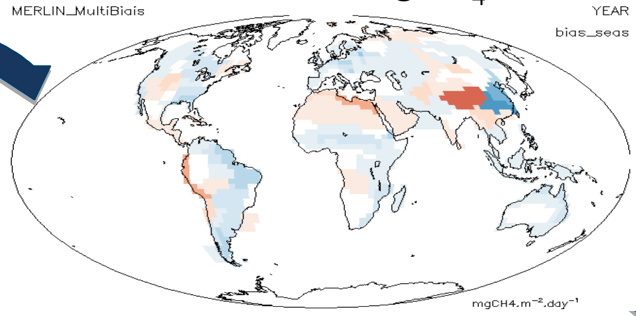
Obs. random errors : 11-80 ppb



Obs. systematic errors : -18/18 ppb



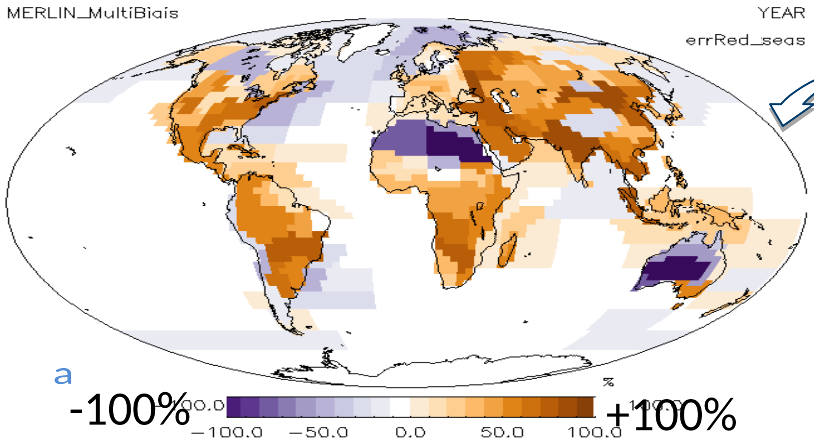
Flux random errors : 0-10 $mgCH_4.m^{-2}.d^{-1}$



Flux systematic errors : -10/10 $mgCH_4.m^{-2}.d^{-1}$

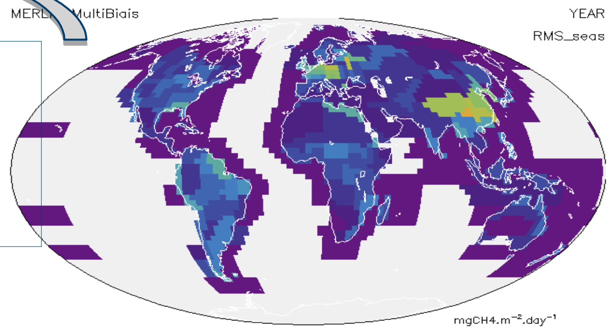
$$\left(1-\frac{\sigma_{posterior}}{\sigma_{prior}}\right)*100$$

Uncertainty reduction



Uncertainty reduction

57% mean Error reduction at continental scale



RMS : 0-11 $mgCH_4.m^{-2}.d^{-1}$

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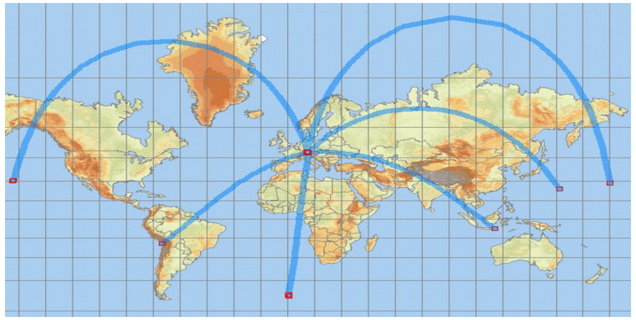
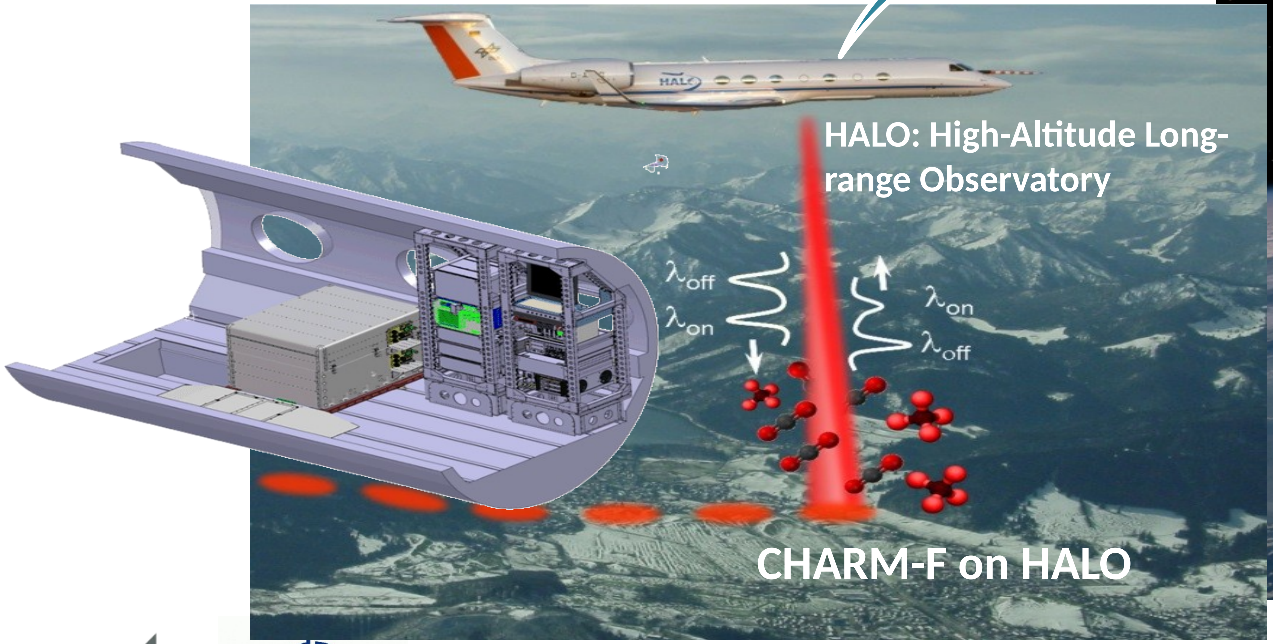
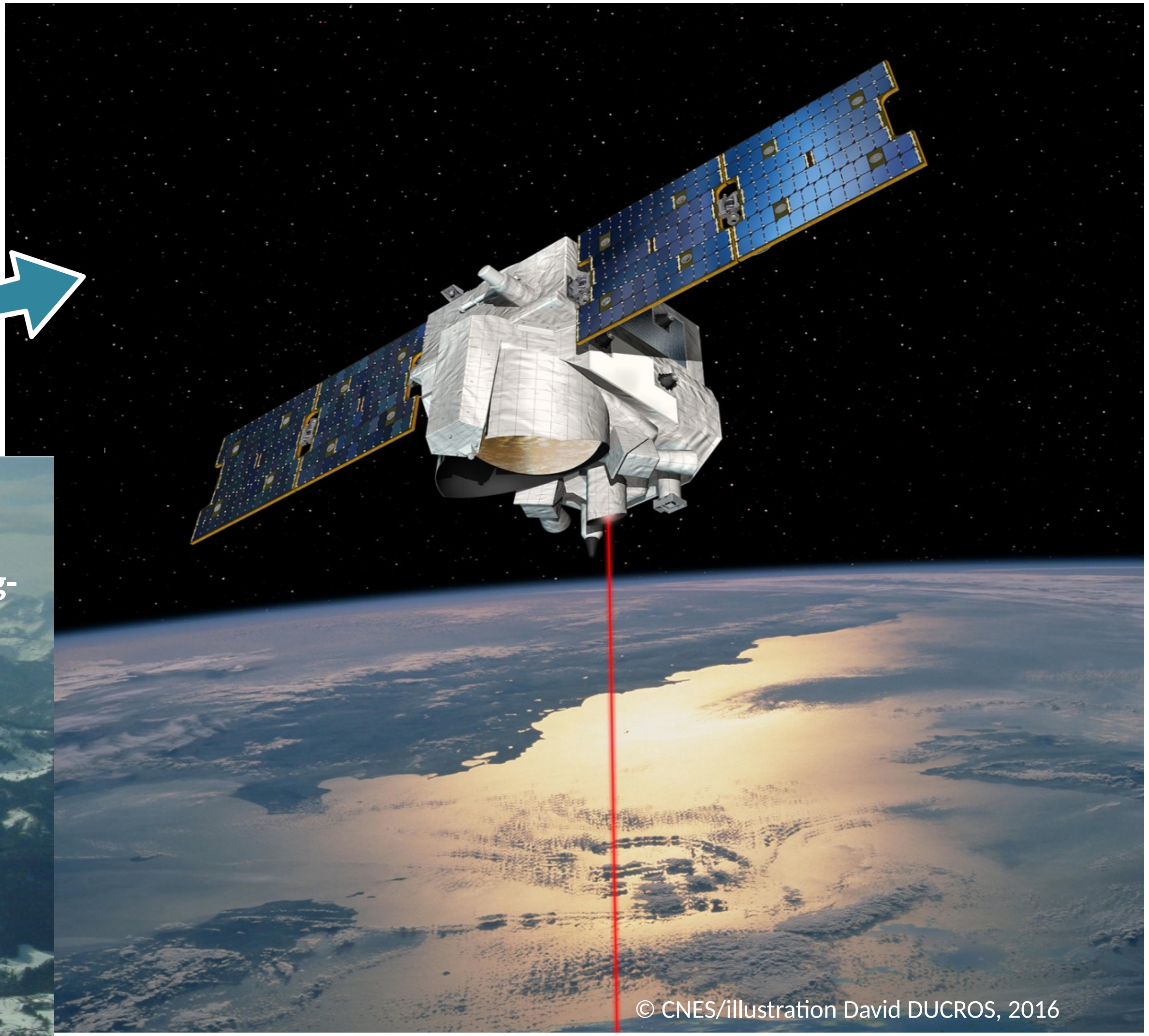
MERLIN Atmospheric Methane Lidar Mission

CHARM-F – DLR‘s Airborne MERLIN Demonstrator
Core Instrument for MERLIN Validation



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





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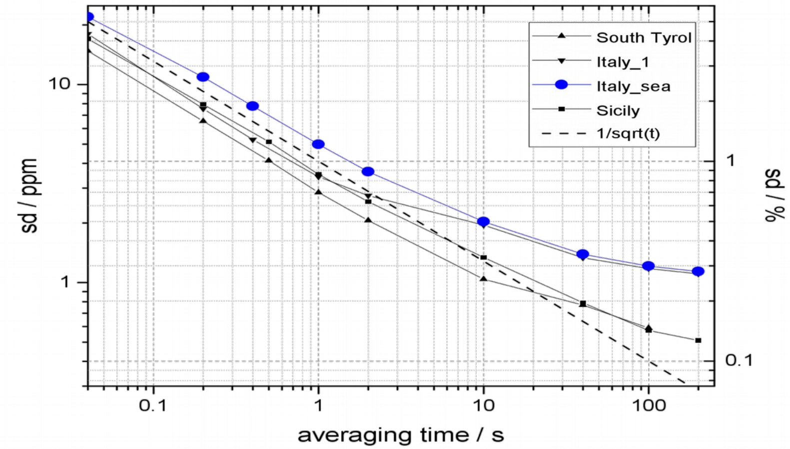
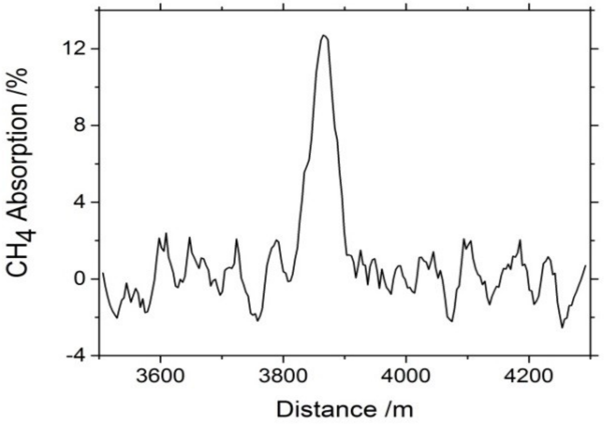
Proof-of-Concept: Results from first CHARM-F test on HALO, 2015

CHARM-F: The new Lidar instrument for the measurement of the greenhouse gases CO_2 and CH_4 on the HALO aircraft



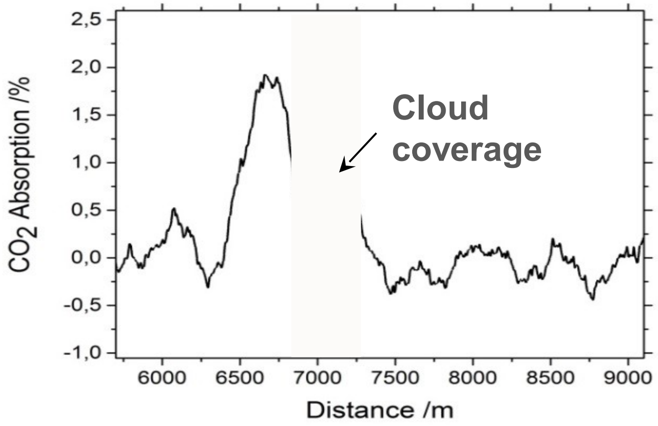
high measurement precision < 0.2%

Amediek et al., Appl. Opt., 2017



Measurement of CH_4 emission from coal mine ventilation shaft in Poland

→ **9 kt CH4 yr-1**

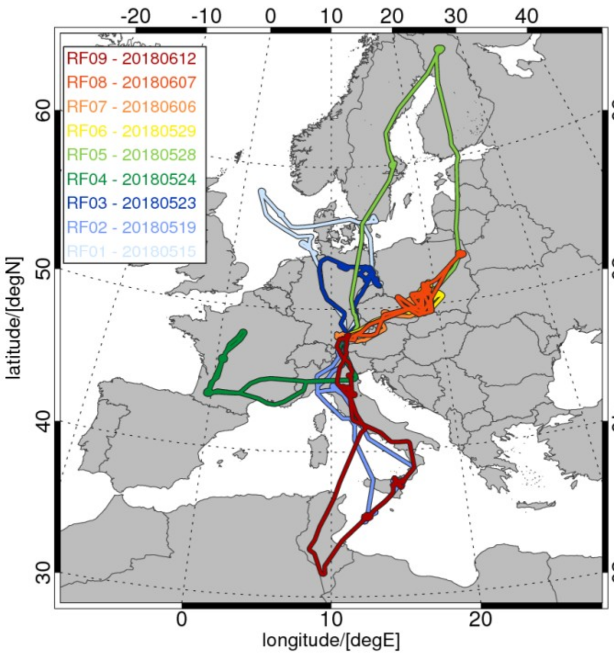


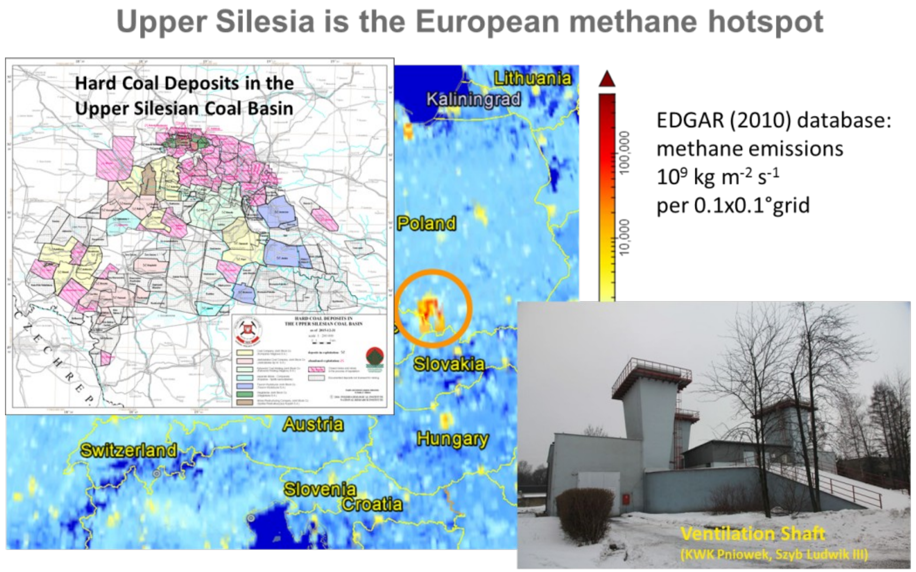
Measurement of CO_2 emission from large power plant in Germany

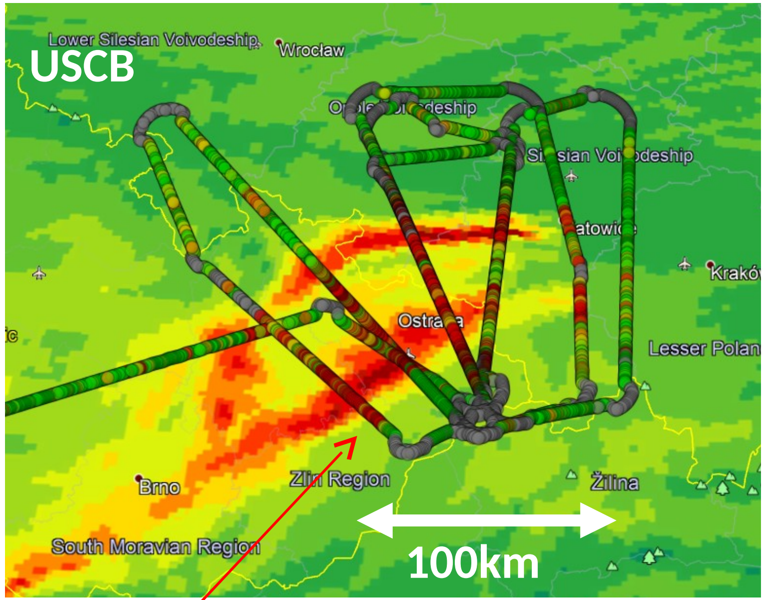
→ **14 Mt CO2 yr-1**

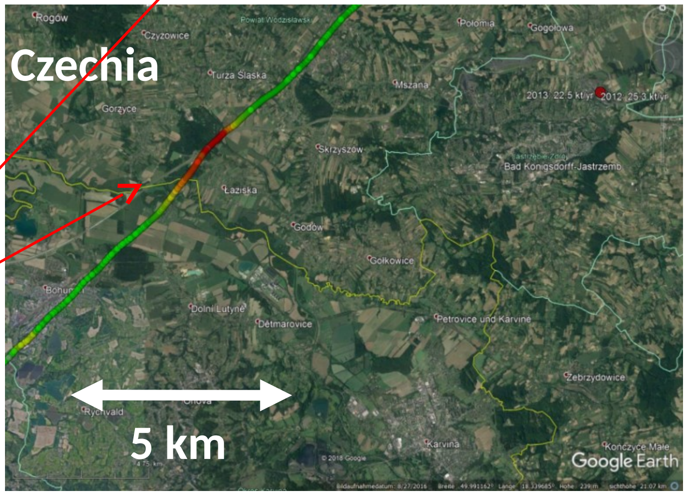
CoMet, 2018

An airborne mission to simultaneously measure CO_2 and CH_4 using idar, passive remote sensing and in-situ techniques







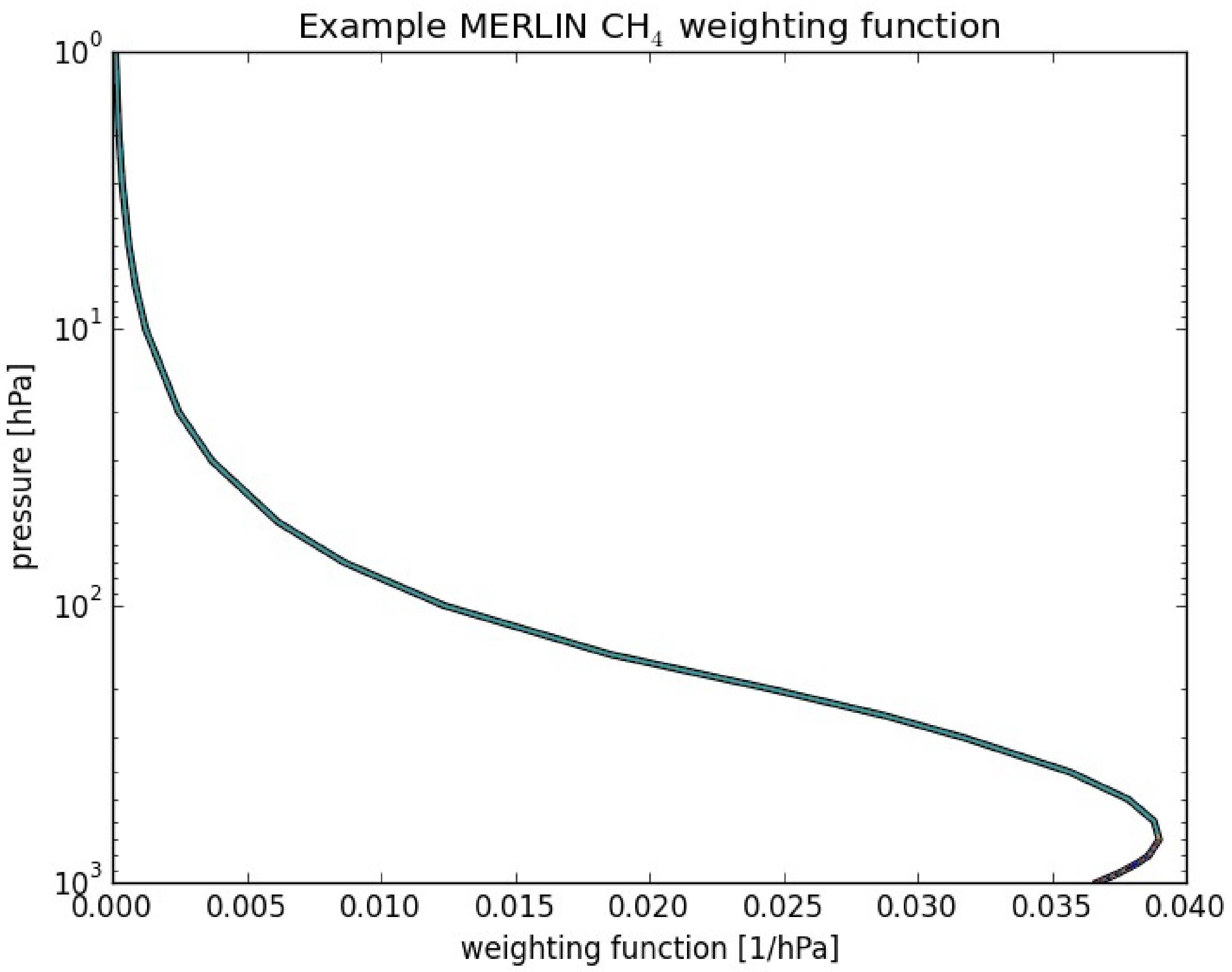


Scientific Flights: May-June 2018, 65 flight hours, 9 flights,Base: Oberpfaffenhofen (EDMO)

CHARM-F quicklook data: Methane distribution in the USCB and Czechia

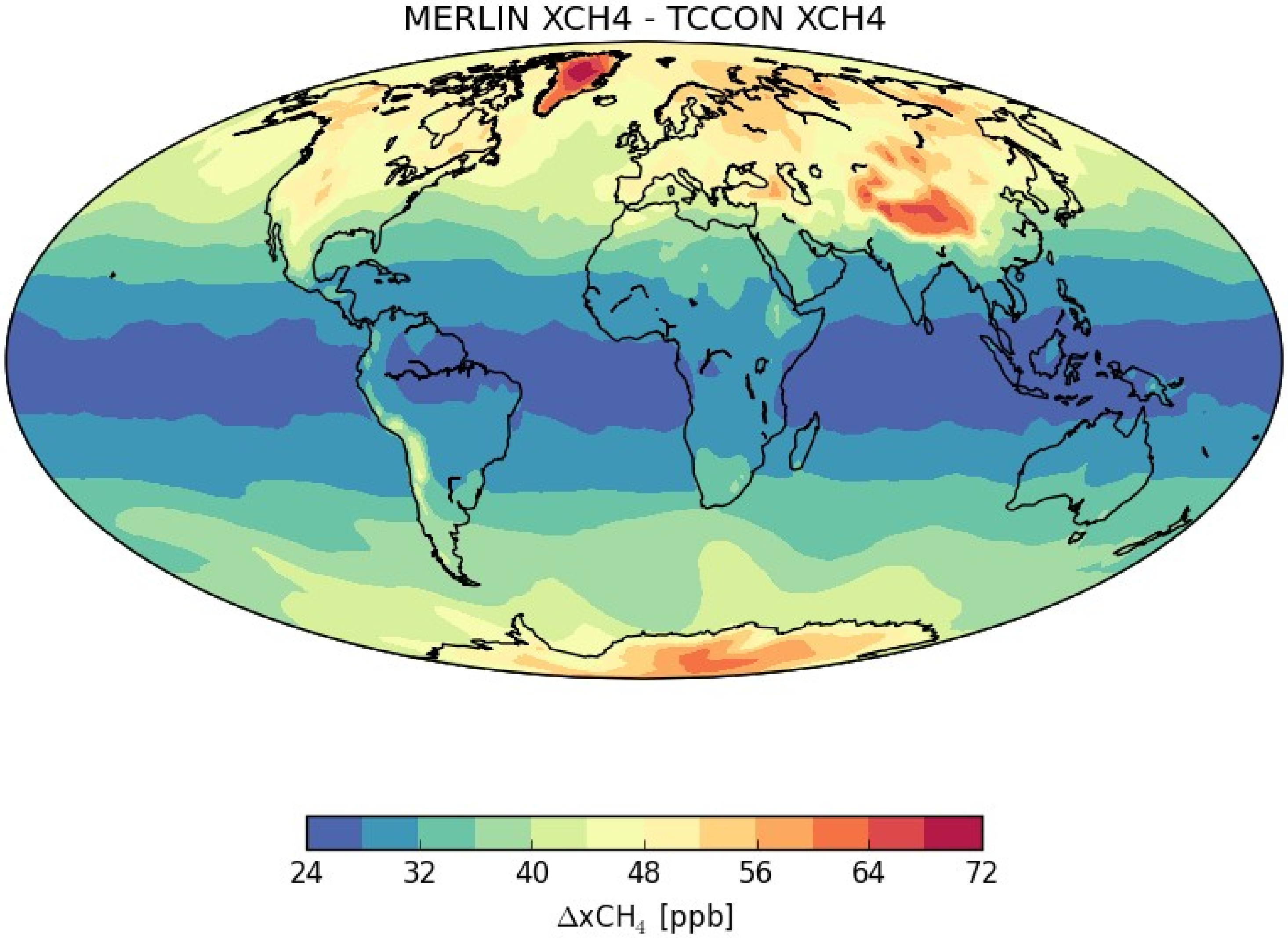
MERLIN weighting functions

- MERLIN weighting functions have a strong peak in the lower troposphere.
- Shape depends on pressure and temperature profile.
- Peak altitude depends on choice of laser wavelength.
- Validation against column observatior will be a challenge.



MERLIN validation: systematic bias due to vertical weighting functions

- Example: simulated CH4 profiles from CAMS data for March 21, 2016 (equinox).
- Apply TCCON averaging kernels and MERLIN weighting functions to each profile.
- MERLIN local overpass time will be 06:00/18:00: assume lowest elevation for simulated TCCON observations.
- Systematic latitude- and altitude-dependent positive 1.3-4% bias found for MERLIN w/o corrections.
- Correction strategy is needed to validate MERLIN with TCCON.



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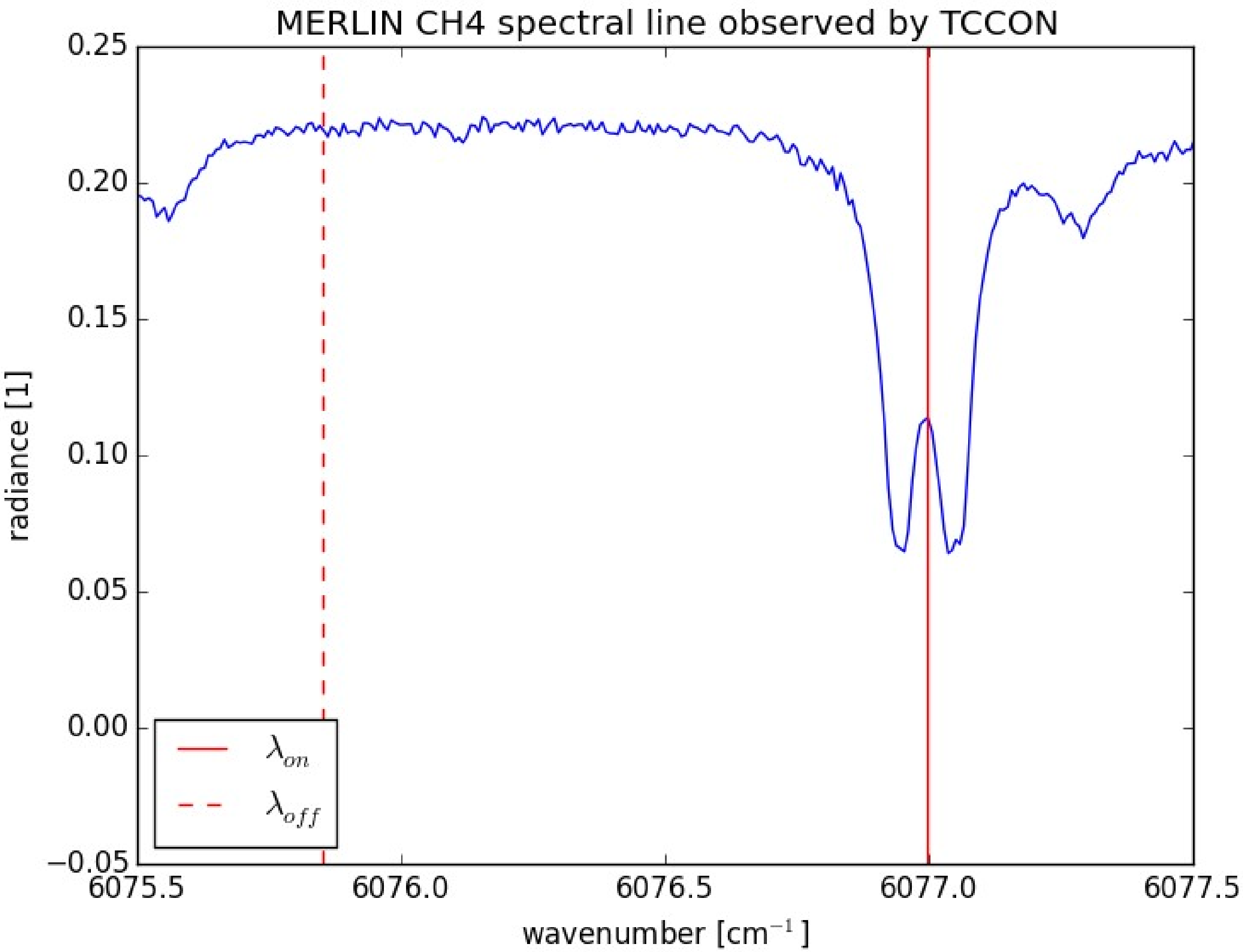
Future work: Investigation of alternative validation strategies

- Use CAMS profiles to correct bias.
- Check if TCCON scaled profiles can be used to minimize bias.
- Validate MERLIN against separated tropospheric partial CH4 columns from TCCON.
- TCCON spectral resolution is only ~3-5 times lower than effective MERLIN resolution: potential for validation on spectral level instead of retrieved column data?
- Application for profile retrieval from TCCON data?



Conclusions

- MERLIN is a challenging, but well-balanced mission
- MERLIN will implement state of the art of space segment design (IPDA-Lidar) for the first time and ground processing architecture to reach the limit of achievable performances for low systematic errors
- Methodology, performance and critical instrument design elements demonstrated by airborne measurements using CHARM-F on HALO
- Validation with TCCON will be a challenge due to the strongly pointed vertical weighting functions.

Acknowledgement

The MERLIN Science Advisory Group (SAG)

"MERLIN: A French-German Space Lidar Mission Dedicated to Atmospheric Methane" Remote Sens. 2017, 9(10), 1052; https://doi.org/10.3390/rs9101052

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