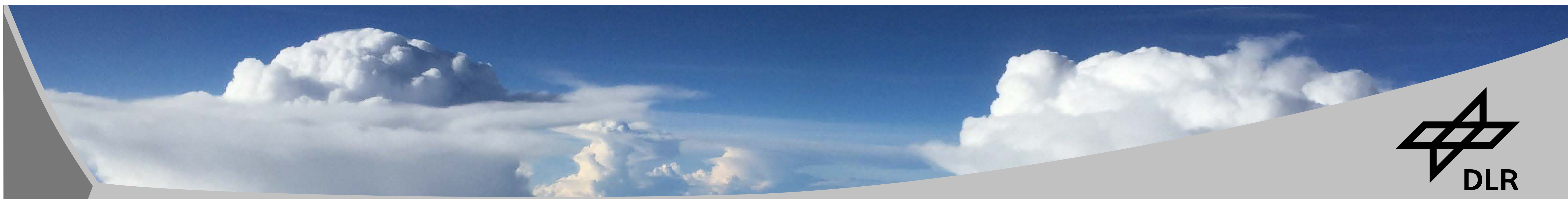
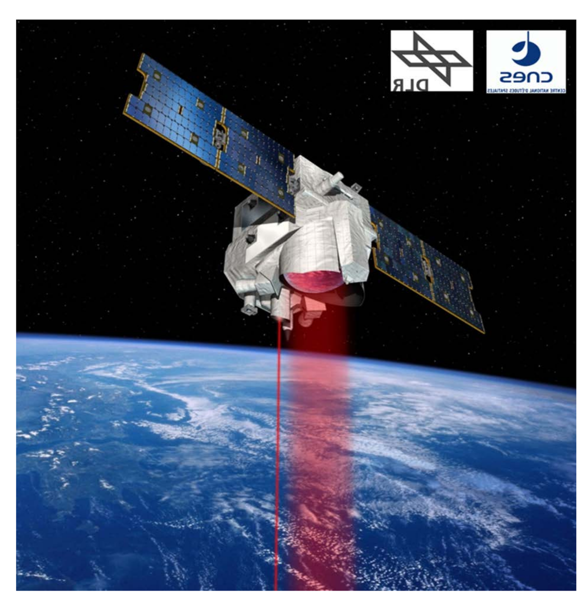


Advanced Determination of Sources and Sinks of Methane

Abstract: We present an advanced method to determine global methane sources, which includes comprehensive atmospheric observations and a state-of-the-art chemistry climate model. The MERLIN Atmospheric Methane Lidar Mission aims at a highly precise quantification of methane sources up to high latitudes. The model-based inverse optimization of emission inventories combines observations and statistical estimation methods to reduce uncertainties in methane sources. The model results further reveal the decisive impact of methane sinks on the emission estimation. Especially global OH still includes large uncertainties and its contribution to the global methane burden is currently highly debated.

MERLIN – Atmospheric Methane Lidar Mission

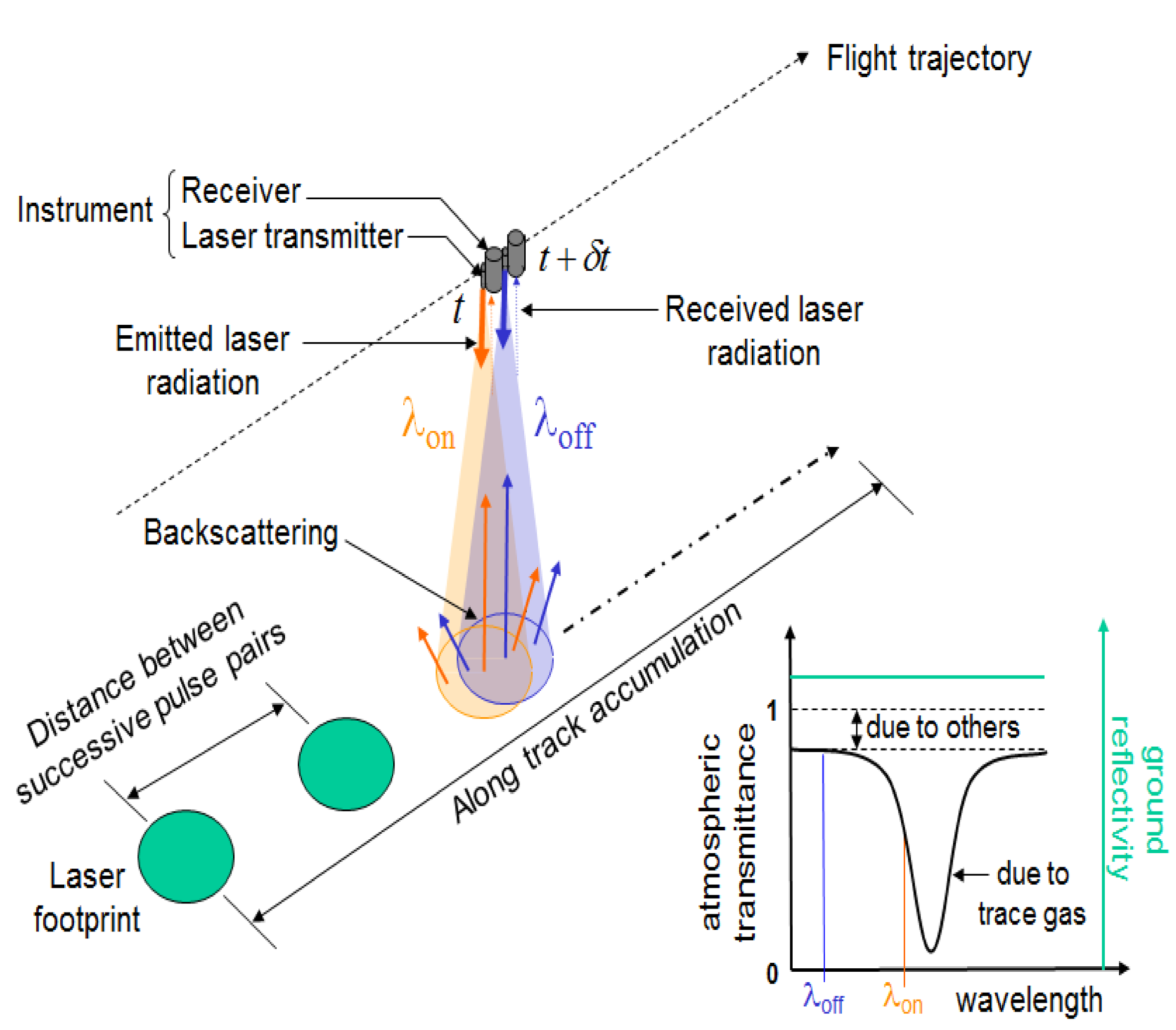
Motivation



- MERLIN is the French-German climate mission for the space-borne active measurement of atmospheric methane (CH_4), a potent GHG (GWP~ 28 x CO_2) with unprecedented accuracy (<0.2%) to constrain regional emissions
- Large CH_4 flux uncertainties (30–40%) for anthropogenic sources and larger than 100% for some natural sources

Approach

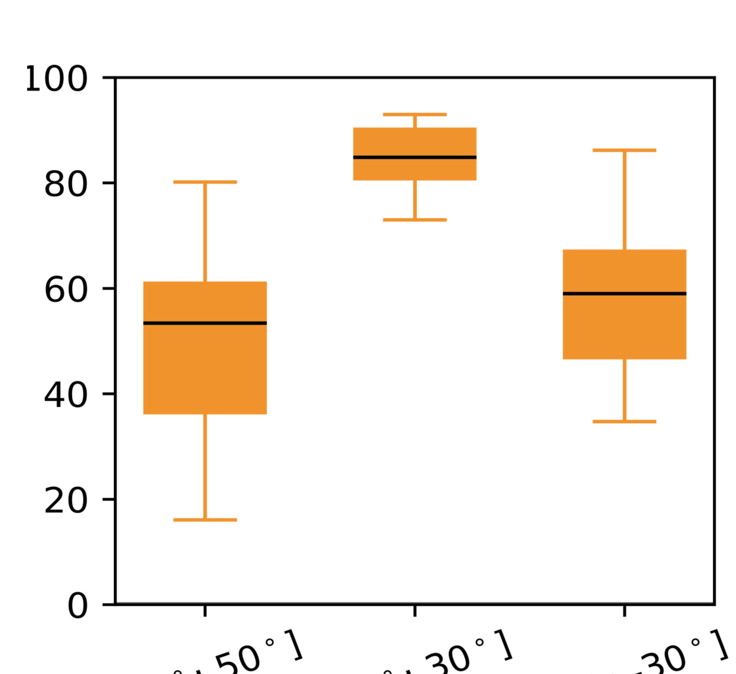
- Integrated path differential absorption Lidar (IPDA)
- Measurement of reflected laser radiation on Earth surface at two wavelengths
- L1 data: Calculation of Differential Atmospheric Optical Depth (DAOD)
- L2/L3 data: Calculation of column-integrated mixing ratio of methane, denoted as XCH4,
- L4 data: Calculation of CH4 surface fluxes using inverse models



Results

Observation System Simulation Experiment:

- Uncertainty reductions on CH_4 emissions are 59% between (30°S–30°N), 84% between (30°N–50°N), and 53% for continental high latitudes above 50°N
- Detector noise has largest impact on the random error of the MERLIN observation (~ 24 ppbv)
- The uncertainty reduction is limited by the detector non-linearity accounting for 2.3 ppbv



Model-based inverse optimization of methane sources

Approach

The **fixed-lag Kalman Filter** optimizes an emission inventory with respect to surface observations y and results of a forward simulation H, given an a priori inventory x^g and assuming an model-observation mismatch error with covariance matrix R and emission error covariance matrix Q^g.

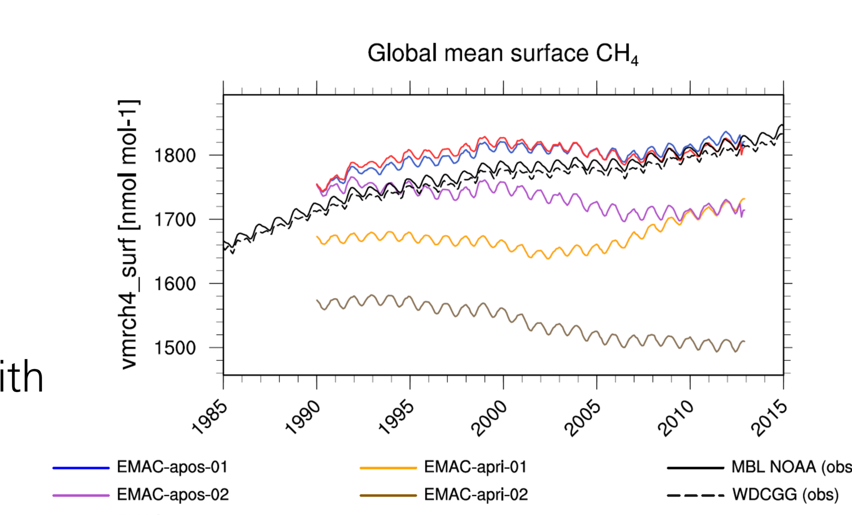
$$\boldsymbol{x^e = x^g + Q^g H^T \left(R + HQ^g H^T\right)^{-1} (y - Hx^g)}$$

$$\boldsymbol{Q^e = Q^g - Q^g H^T \left(R + HQ^g H^T\right)^{-1} HQ^g}$$

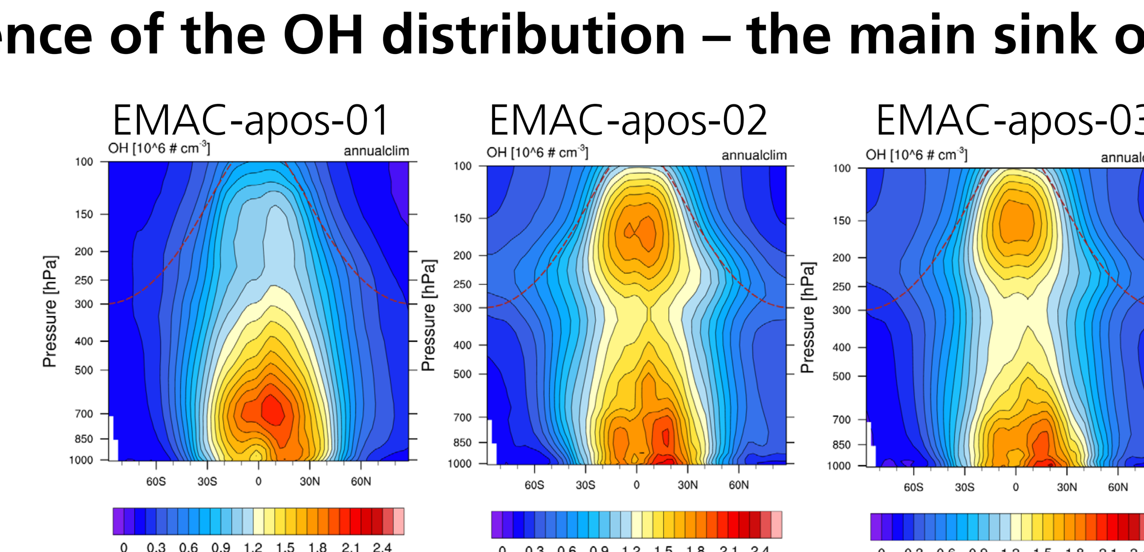
Forward simulations with an optimized emission inventory

Simulation	OH distribution	chemistry
EMAC-apos-01	multi model mean, annually repeated	simplified
EMAC-apos-02	transient, from a previous interactive simulation	simplified
EMAC-apos-03	interactive (incl. feedbacks from CH_4 emissions)	interactive

- A posteriori inventory improves the agreement with observations
- Best agreement with simulation using the annually repeated OH and the interactive chemistry.
- The inter-annual trend is not represented by the simulation with transient OH.
- The assumed sink of CH_4 determines the emission inventory and the simulated CH_4 burden.

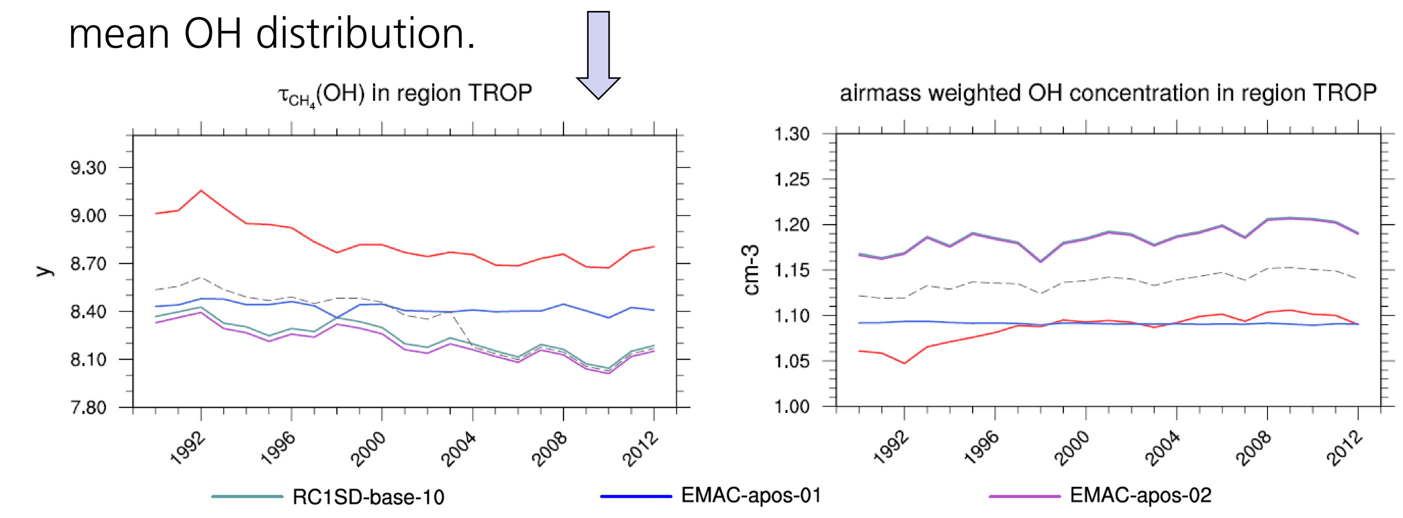


Influence of the OH distribution – the main sink of CH_4



Figures: Zonal mean OH distribution of the indicated simulations. Climatological annual mean of the years 2000-2009.

- Feedback onto the OH concentration due to increased emissions and CH_4 burden in the interactive chemistry.
- Strong increase in the CH_4 lifetime and comparable air-mass weighted OH concentration of the interactive derived OH distribution to the multi model mean OH distribution.



Figures: (left) Tropospheric CH_4 lifetime. (right) Tropospheric air-mass weighted OH concentration.

⇨ Knowledge on the total atmospheric OH concentration is required for an accurate emission estimation.

To reduce present uncertainties in the global methane emissions, sources and sinks must be considered jointly!

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