Project: **1231**

Project title: **CAMELOT:**

Principal investigator: **Julia Marshall**

Report period: **2023-11-01 to 2024-10-31**

WP1 - Regional greenhouse gas inversions using WRF-STILT

For a first emission estimation using Geostatistical Inverse Modelling (GIM), we selected a case with a well-developed boundary layer, stable wind speed and direction and a flight pattern that sampled inflow and outflow at different altitudes. The average emission rate in the evaluated area is about 8 kg(CH_4) km^{-2} day^{-1} according to the inventories used as prior. Scaling the emissions to the observations with a regression model that leaves the prior flux pattern unchanged results in a flux estimate of 26 kg(CH_4) km^{-2} day^{-1}. Additional optimization of the flux pattern gives an emission estimate of 37 kg(CH_4) km^{-2} day^{-1}. The optimized, posterior emissions for this case indicate that the bottom-up models underestimated the emissions by a factor of about five. Figure 1 shows how the prior and the optimized emissions compare to the observations. An uncertainty analysis is pending. This work has been presented at two conferences this year (both Gottschalk et al., the MAGIC workshop, Palaiseau, France, 09.07.2024 and the CLM Community Assembly, Oberpfaffenhofen, 22.10.2024) and will be prepared for publication in the coming months.

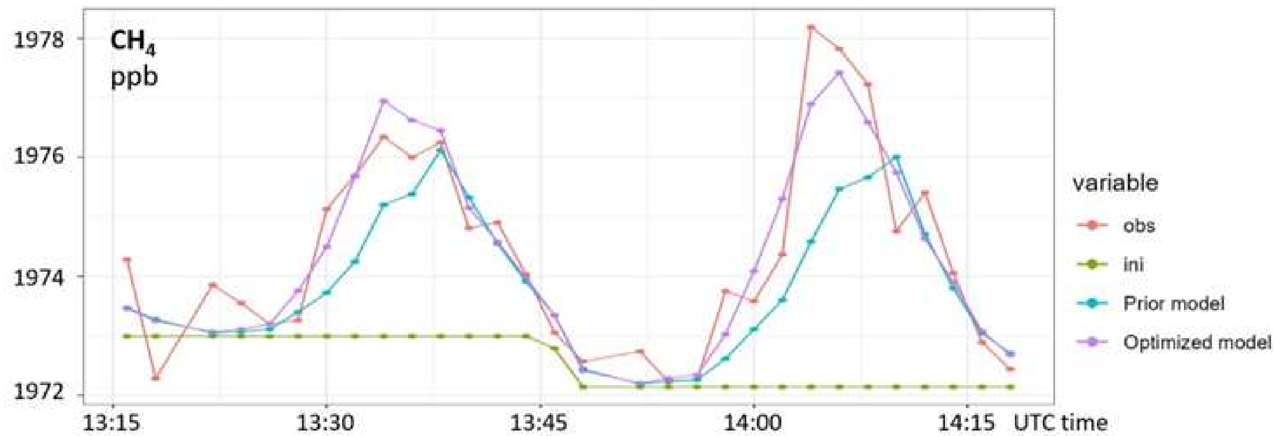

Figure 1: Timeseries of atmospheric methane mole fractions. Observed (aircraft in-situ measurements), background (average downwind of the analysed area), regression model (JSBACH-HIMMELI for wetlands + Johnson et al., 2022, for lakes, scaled), and posterior emissions (i.e., the final result).

Additionally, we finalized the analysis of atmospheric methane observations obtained around the Nord Stream leaks from September-October 2022 (the analyses were reported on in WP4 in the last report). We quantified the outgassing of methane from the Baltic Sea that had previously dissolved at the leak sites based on airborne measurements, and related our results to ocean process models of the fate of the methane. In addition to the Lagragian footprints using STILT and atmospheric inversion, a marine particle dispersion model was developed and run on Levante for this study. The corresponding first-author publication has been accepted to Nature Communications (Reum et al., 2024 [accepted]), and the work is also part of a larger synthesis paper to be published in Nature (Harris et al., 2024 [accepted]).

WP2 - Global greenhouse gas inversions

Inversions carried out in this WP formed the basis for the Climate Assessment Report #8 in the GHG-CCI+ project (ESA). A poster looking at the impact of digital elevation models was presented at the International Workshop on Greenhouse Gas Measurements from Space (IWGGMS) in Boulder.

WP3 - Development of AI methods for plume detection and biogenic flux estimation

In the development of AI-driven methods for the estimation of emission rates for point sources we succeeded in transitioning our advances on artificial to realistic noise scenes. In addition to these improvements, we were able to obtain relevant error estimates for the predicted emission rates. We presented these advances at the IWGGMS and submitted a publication ('Improvements of AI-driven emission estimation for point sources applied to high resolution 2-D methane-plume imagery') that is currently under review. Our advances include improvements of the performance, as well as new insights into limitations of AI-based methods. As further steps we plan on using the obtained insights to further develop the methodology and move towards experiments involving transitions to real data. The current performance of our model is shown in Fig. 2.

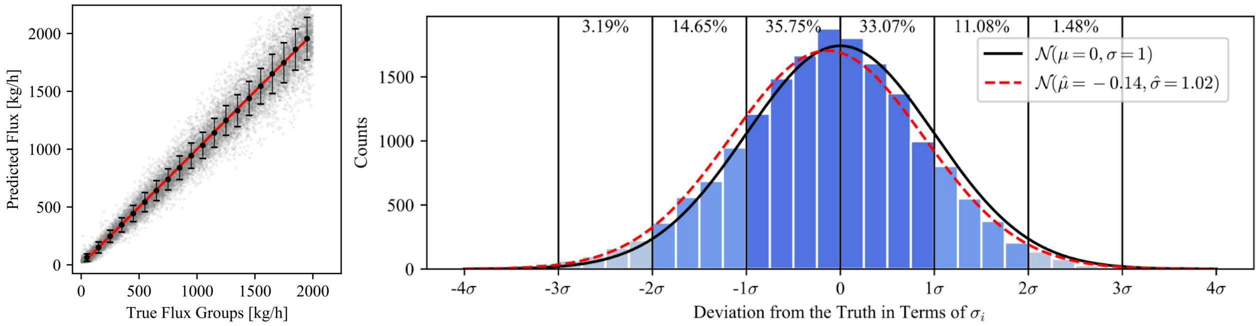

Figure 2: Performance of the current deep learning model for point source flux estimation for the AVIRIS instrument (left) and the distribution of the estimates with respect to their respective error estimates (right).

Additionally, development of a next-generation implementation of the VPRM biospheric flux model is complete and will be submitted for publication presently. This work was presented at the International Carbon Dioxide Conference in Manaus.

WP4 - Plume dispersion modelling and analysis for aircraft campaigns

Dispersion modelling with STILT was carried out to assess the feasibility of taking part in a controlled methane release experiment in Lacq, France, in September of this year. Our campaign would have involved in situ measurements taken from a helicopter-borne suspended platform (HELiPOD). The results were analyzed taking into account the no-fly radius around the leaks and the planned rates of emission, leading to a no-go decision.

WP5 - LES modelling of plumes

The modeling of LES plumes has been inactive for most of the reporting period, but has recently been reactivated with the hiring of a student to carry out the work. We have successfully simulated plumes at 200 m resolution. Currently, we are working on achieving finer resolutions. More specifically, we are attempting to solve or work around memory corruption problems in the WRF model when run on Levante.

WP6 - Inverse modelling of CH_4 emissions from oil and gas facilities and natural wetlands in Canada

We applied a χ^2 inversion method for CH_4 emissions to data from a flight campaign (CoMet 2.0), with the transport operator provided by WRF-Chem simulations. The method was initially tested on research flights over Madrid landfills, where the known emission source allowed for performance validation. The Madrid simulations were presented at an international conference (C. Fruck et al. at the 31st ILRC) and a paper draft is in progress.

Following this, the method was applied to the more complex case of oil and gas exploitation facilities near Lloydminster, Saskatchewan, Canada, where the exact emission locations are less clear. Preliminary results show a strong influence of topography, with nocturnal accumulation of CH_4 in river valleys playing a significant role in transport. Despite this complexity, our approach achieved a strong agreement between model and data (see Figure 3), which was also presented at an international conference (C. Fruck et al., EGU24-9599). Further investigation is ongoing to understand the spatial allocation of emission sources and topography's effect on quantification.

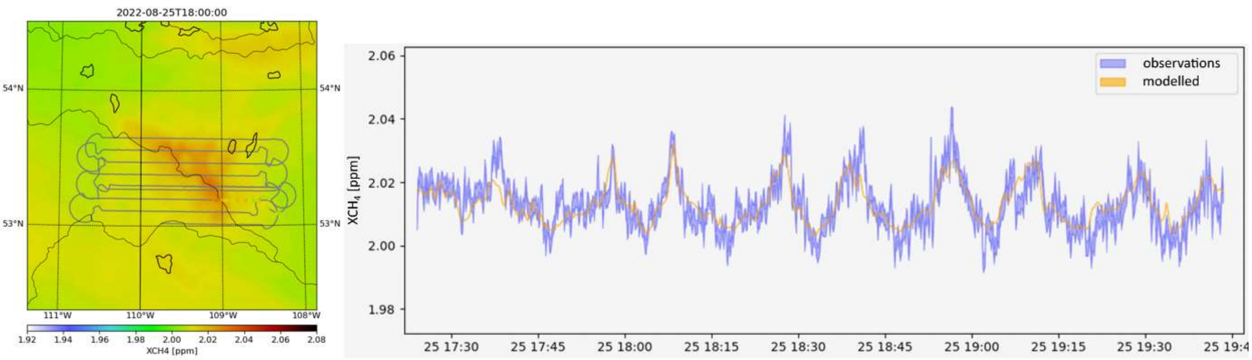

Figure 3: Column-averaged methane concentration (XCH_4) from WRF simulation at time of measurement on 25th of August 2022 after fit (left). Simulated and measured XCH_4 after fit as a time series along the flight track (right). Preliminary results from Analysis of Lloydminster oil and gas fields data set.