Project: **1231**

Project title: **CAMELOT**

Principal investigator: **Julia Marshall**

Report period: **2024-11-01 to 2025-10-31**

WP1 - Regional greenhouse gas inversions using WRF-STILT

The WP1 activities related to MAGIC 2021 in the previous request were delayed. Footprints have been calculated with WRF-STILT for the first of the CoMet 2.0 flight to be analyzed, focussing on a wetland region near Lake Winnipeg. The previous WP1 work quantifying methane emissions from the Nord Stream explosions using WRF-STILT and the geostatistical inversion method were published as Reum et al. (2025) and included in the synthesis paper Harris et al. (2025).

WP2 - Global greenhouse gas inversions

Work in WP2 was delayed due to hiring of new staff for the projects DiSMISS and CH4DAS. (One scientist started only in September, 2025, and the other is still waiting for a visa.) Nonetheless, work on elevation-related biases in satellite data continued, and was presented at an international conference (Marshall et al., 2025). It is currently being prepared for publication. The GHG-CCI+ project start was delayed for administrative reasons, and the results will be reported next year.

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

The work on AI plume detection and emission quantification from the previous report has since undergone peer review and was published (Plewa et al., 2025). Currently, we work on further improving the performance of the method by implementing a mixture-of-experts approach, where separate models are trained for different wind speed regimes, and a router determines which “expert” model to apply. This has resulted in significant reduction in the spread of the resultant emission estimations, as shown in Fig. 1. This work is currently being prepared for publication. The next-generation version of the VPRM model, pyVPRM, has been published (Glauch et al., 2025) and has already experienced substantial uptake in the scientific community (e.g. Storm et al., 2025).

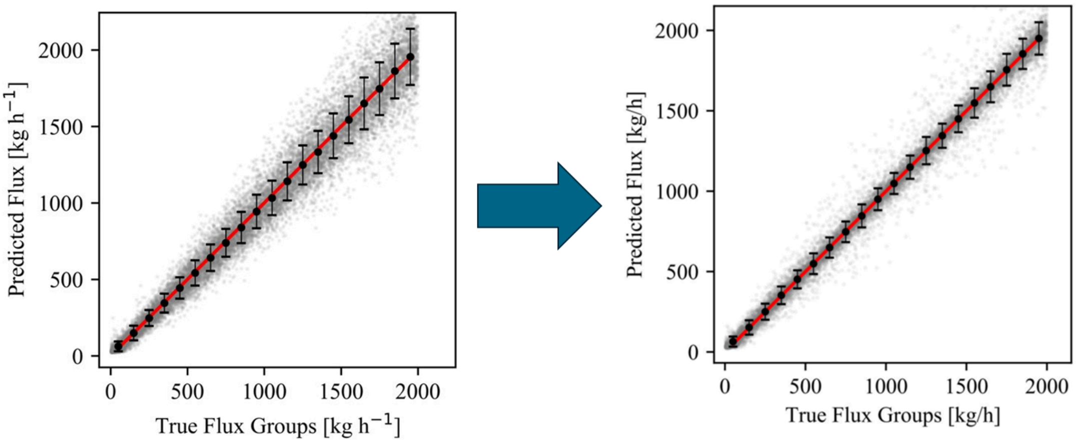

Figure 1: The improvement in the emission estimation from the version published by Plewa et al. (2025) and the mixture-of-experts implementation currently being prepared for publication. The new model substantially reduced the spread in the emission estimates.

WP4 - Plume dispersion forecast and analyses for aircraft campaigns

No ad hoc campaign planning simulations were carried out in 2025.

WP5 - LES modelling of plumes

In this work package, we investigated the influence of turbulence on emissions estimated using observations of CO_2 mole fractions obtained from airborne platforms using the mass balance method (Ma, 2025). Using one day of LES plumes, simulated on 50-m horizontal grid spacing with the WRF model, we quantified the uncertainty of estimated emissions for varying flight paths. One result is that the accuracy of estimated emissions degraded when the minimum flight was above the plume emission height (Fig. 2). This work supports the flight planning of future airborne campaigns.

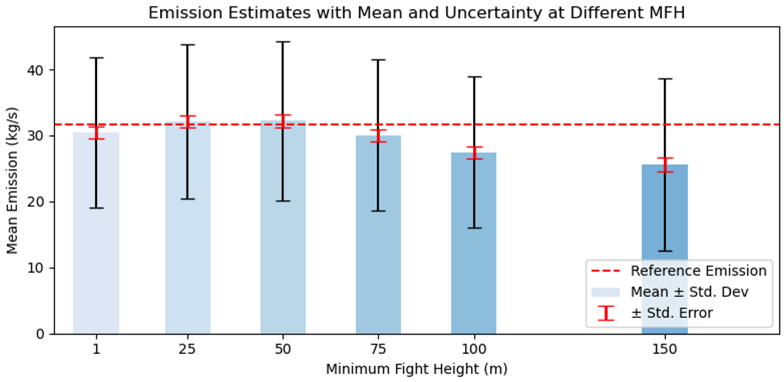

Figure 2: For the mass-balance method, a "wall" of flight legs across a plume is flown. Here we show the influence of the height of the lowest flight leg on estimated emissions.

In addition, we simulated LES plumes for investigating observation concepts for hydrogen emission estimation. These simulations require a smaller grid spacing, since hydrogen observations will require observations closer to the source than for CO_2. Figure 3 shows a first simulation with 10-m grid spacing.

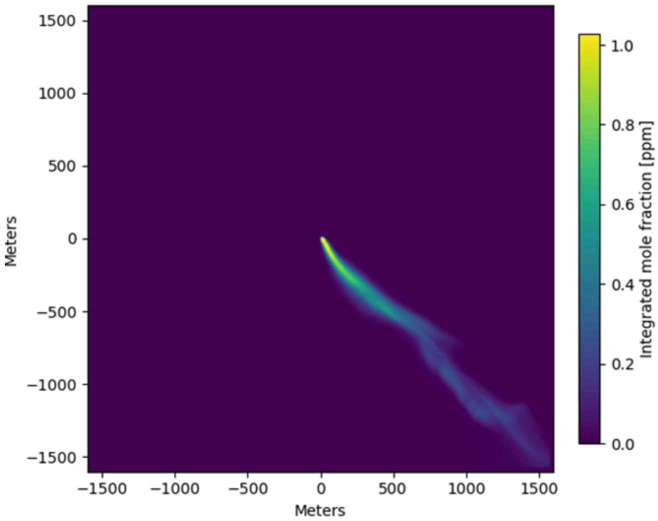

Figure 3: Snapshot of a simulated tracer plume with 10-m horizontal grid spacing. Shown here is the average mole fraction across the plume height, scaled for a source of 400 kg H_2 per day.

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

We completed the χ² inversion study of CH_4 emissions from the Madrid landfills, based on CoMet 2.0 flights. This work relied on WRF-Chem simulations, where individual source components were assigned tracers and optimized through χ² fitting. The Madrid case provided an ideal testbed for method validation, as the true emission source is well constrained. The simulations are completed and have been presented at international conferences (C. Fruck et al. at the 31st ILRC). A publication draft is in progress and expected to be submitted before the end of 2025.

In addition, the focus of WP6 in 2025 remained on the completion of the inversion studies for the Upper Silesian Coal Basin (USCB). These analyses, based on CHARM-F data and the WRF-CTDAS system, are now finalized. By applying a novel inversion-driven clustering approach, in which individual coal mine ventilation shafts were aggregated into 13 emission clusters, posterior emission estimates were obtained for each cluster. The total basin-wide emission amounts to 570 ± 78 kt/yr, about 16 % higher than officially reported inventory data. Within uncertainties, these results are consistent with independent observation-based studies. For additional sensitivity analyses, in particular on background representation, we consumed just over 800 node hours in 2025. The work was included in the PhD thesis of Sebastian Wolff (submitted at LMU on 30 October, 2025) and a corresponding publication is currently being prepared for submission this year.