Project: **1231**

Project title: **CAMELOT:**

Principal investigator: **Julia Marshall**

Report period: **2022-11-01 to 2023-10-31**

WP1: Regional CO_2 inversions for Europe

This work took part mostly within the CoCO2 project, which is drawing to a close. Regional inversions with WRF-CIF (coupled to the Community Inversion Framework within the project) are part of an intercomparison project currently being prepared for publication. Additional inversions with WRF-CTDAS using satellite data and in-situ data, as well as simulated CO2M data, are part of two project deliverables currently under preparation, and will be subsequently written up as publications.

WP2: Global methane inversions

Inversions carried out in this WP formed the basis for the Climate Assessment Report #7 in the GHG-CCI+ project (ESA), and were also included in the final report of the ESA project Methane+.

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

One part of WP3 is devoted to the development of novel methods for the estimation of biogenic fluxes (exchange of carbon-dioxide between atmosphere and the earth biosphere) on different spatial scales by combining artificial intelligence with satellite data and meteorological drivers. In addition to algorithmic advances also new high-resolution satellite data are becoming available. Hence, our advances are twofold: We have 1.) trained deep neural networks to predict net ecosystem exchange (NEE) and gross-primary productivity (GPP) on regional, continental and global scales using the MODIS satellite and 2.) We have re-implemented the vegetation photosynthesis and respiration model (VPRM, Mahadevan et al. 2008) to incorporate data from future-oriented satellite missions such as VIIRS, Sentinel-2, as well as updated high-resolution land cover maps. VIIRS is the drop-in replacement for MODIS and therefore guarantees long-term data continuity. Sentinel-2 has improved spatial resolution and is therefore specifically relevant for inverse model applications on city-scale as for example in the H2020 ICOS Cities project (who are using these data).

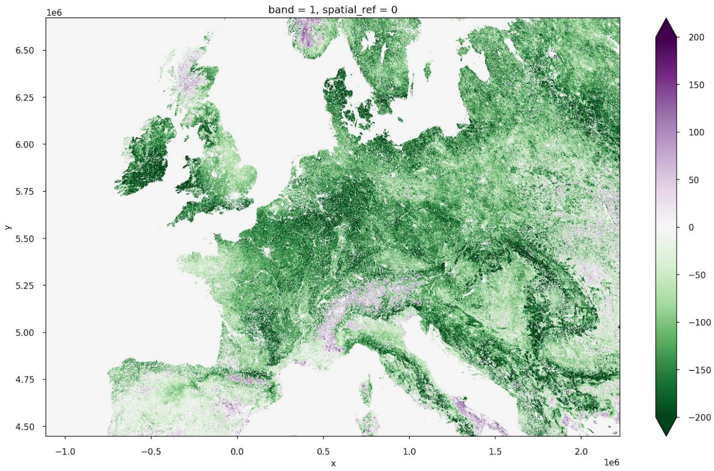

Figure 1: Cumulative net ecosystem exchange (NEE) for central Europe on the 5th of June 2022 in units of μmol CO_2 m^{-2} day^{-1}) in full MODIS resolution. Negative fluxes indicated that photosynthetic carbon uptake exceeds respiration.

The work on the emission estimates for point sources shows steady progress. Due to improvements of the training process and the network architecture the results for artificial noise were improved significantly compared to the prior state of the art (Jongaramrungruang et al., 2021). The current model is capable of producing improved flux estimates, which no longer show significant biases regarding relevant flux ranges or different wind situations. The next step is transitioning these improvements to realistic noise scenarios and trying further network architectures. The current model performance is shown in figure 2.

WP4: Plume dispersion forecast and analyses for aircraft campaigns

Plume dispersion modelling was carried out for flight campaigns in Africa and the Middle East. Furthermore, analysis of research flights in late 2022 around the NordStream leak were carried out. A publication is currently under preparation.

WP5: LES of plume evolution in the marine boundary layer

The initial simulations carried out in the work package have helped us develop the techniques to better model highly-resolved plumes for ongoing projects in support of remote sensing imager data, such as SCARBO2 and ITMS-HIRES, and improve our simulations of plumes as training data for the AI methods in WP3.

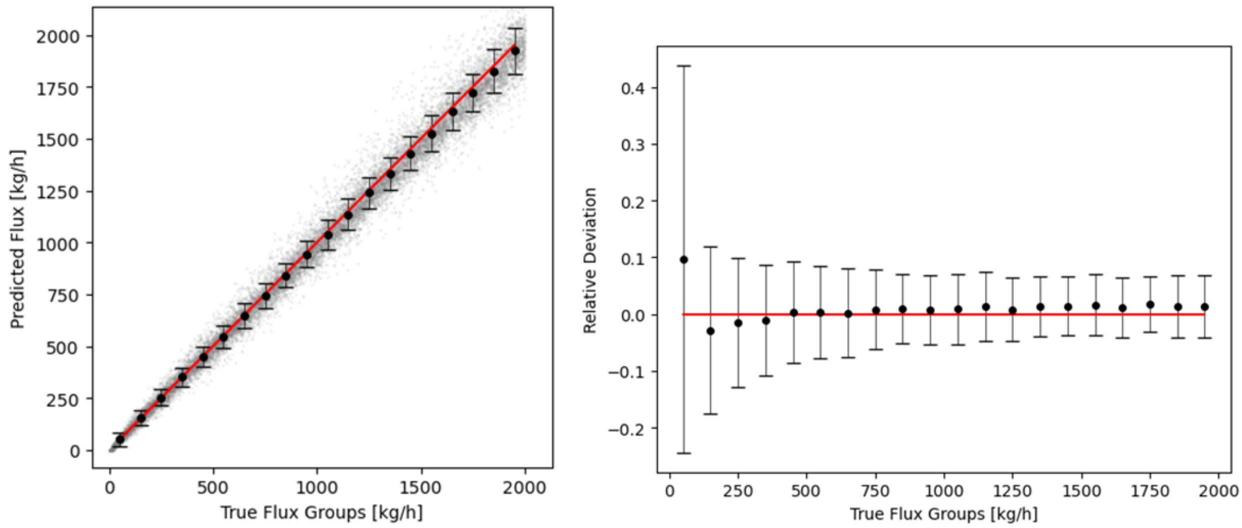

Figure 2: Performance of the current deep learning model for point source flux estimation for the AVIRIS instrument

WP6: Inverse modelling of methane emissions in the Upper Silesian Coal basin

We can report that the combination of CHARM-F measurement data and WRF-CTDAS is a useful tool to determine emission rates of coal mine shafts in the Upper Silesian Coal Basin. The emission rates of aggregated/clustered shafts could be determined and for all clustered shafts an uncertainty reduction, compared to the a priori estimates, could be achieved (see Figure 3b).

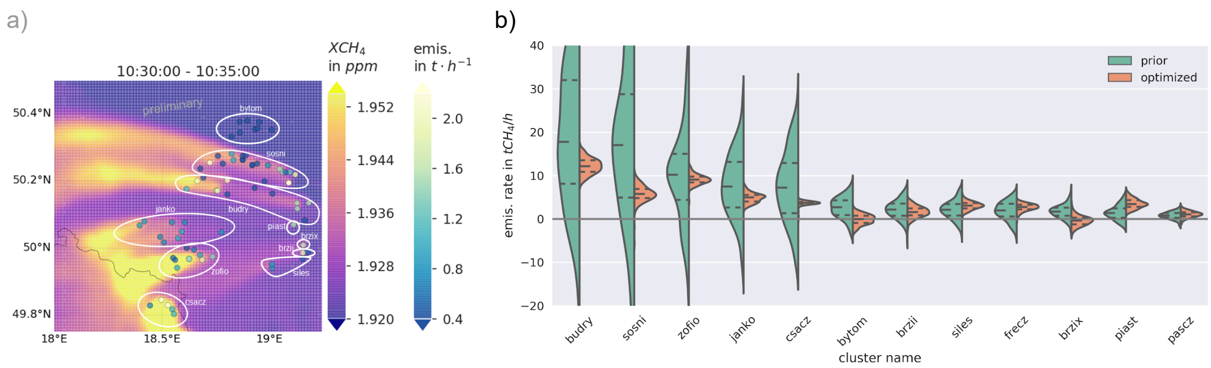

Figure 3: a) snapshot of the forward simulation at 10:30 – 13:35 local time using prior emissions for the ventilation shafts and clustered shafts encircled in white. b) violin plots of the ensemble distributions of clustered shafts emissions (a priori in green; a posteriori/optimized in orange).

Multiple release heights were simulated in order to assess the influence of errors in the vertical mixing within the transport model. With regard to the total emission of all considered shafts a variation of up to 12% was found. Next to the variations in horizontal transport, the false representation of regional gradients of the background CH_4 concentrations, i.e. the CH_4 that is undisturbed by the ventilation shafts' emission, has been found a major source of uncertainty in the a posteriori emission estimates. To assess the influence on the emission estimates, multiple inversion runs were performed, excluding background-constraining observations upwind of coal mine ventilation shafts. The quantitative result of this investigation is still pending at the time of this report. The results were presented at the AGU Fall Meeting 2022 in Chicago (A42L-06 https://agu.confex.com/agu/fm22/meetingapp.cgi/Paper/1146192).
With regard to the requested resources it should be noted that within this work package 2400 node hours were consumed, which is approx. 70% more than the requested 1400 node hours. This can mostly be explained by additional runs that were needed to find an ideal configuration for the aggregation of ventilation shafts. The resources could be allocated within the project, but we have learned that the approach in combination of WRF and CTDAS is more resource-intensive than initially anticipated. We will have to take this into account in upcoming requests.
We have not yet made use of the storage space in the archive, as the work in this WP is still ongoing. However, in the fourth quarter it will be completed and a publication of the results is planned. In this process, the associated data will be archived.

References

S. Jongaramrungruang et al. "MethaNet – An AI-driven approach to quantifying methane point-source emission from high-resolution 2-D plume imagery". In: *Remote Sensing of Environment* 269 (2022), p. 112809. issn: 0034-4257. doi: https://doi.org/10.1016/j.rse.2021.112809.