Project: **1170**

Project title: **Atmospheric greenhouse gases and the Carbon cycle (AtmoC)**

Principal investigator: **Andre Butz, Sanam Vardag**

Report period: **2022-05-01 to 2023-04-30**

Modelling CO_2 and fossil fuel tracer concentration fields in urban hotspots using the WRF-Chem model

We have performed a comprehensive sensitivity analysis of forward runs using WRF on 1km x 1km resolution for the Rhine-Neckar region. We have extended the time period of the analysis to four full months and have investigated a suite of 12 different configurations. We further built in high resolution input data for landuse and topography. The goal was to identify the optimal high-resolution setting for every season and to identify and quantify possible model biases for each season. These realistic meteorological simulation results using WRF at 1km resolution are essential for analyzing greenhouse gas observation strategies in the BMBF-project "Integriertes Treibhausgas Monitoring System" (ITMS) and will be the basis for the next DKRZ project.

We have found that the planetary boundary layer height as well as the wind speed are much more sensitive to the parameter suite than wind direction. The Urban Canopy Model (UCM) outperformed the Building Effect Parametrization (BEP) in most situations. The choice of input resolution had little effect on the simulation and only slightly improved simulations in urbanized areas. We further found that model results were worse for the winter especially with respect to the PBLH. However, the PBL schemes myj and ysu together with the land surface model NOAH MP gave the best results. These results were presented at the AGU conference 2022 (Pilz et al., 2023) and the general ITMS meeting.

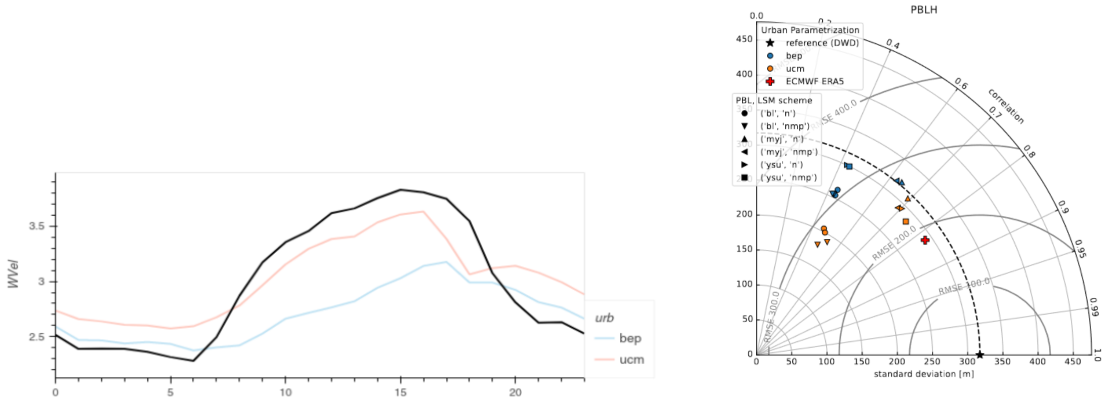

Figure 1: left) Diurnal cycle of wind velocity during spring time (01.-30.04.2020) can be best captured using the UCM scheme. right) Taylor plot for analysis of planetary boundary layer height in winter (01.12-31.12.2020) Black star: Radiosonde height reference data. Colors: WRF-Simulation results using different physics schemes. Red diamond: ECMWF data for the same exemplary time period. From PhD candidate Lukas Pilz.

For a prototype region of Berlin, we used the WRF-Chem model and implemented tracer fields, such as CO, biogenic CO_2 and anthropogenic CO_2. We simulated the concentration maps for Berlin on 1km resolution in order to draw first conclusions on a potential choice of sensor locations (see Fig. 2). We found that large point sources in the vicinity of the city have a dominating influence in the total signal. Separating concentration enhancements from these point sources will be important to determine inner city emissions. Further, biogenically driven concentration changes cannot be neglected. Especially in summer they contribute substantially to the concentration enhancements.

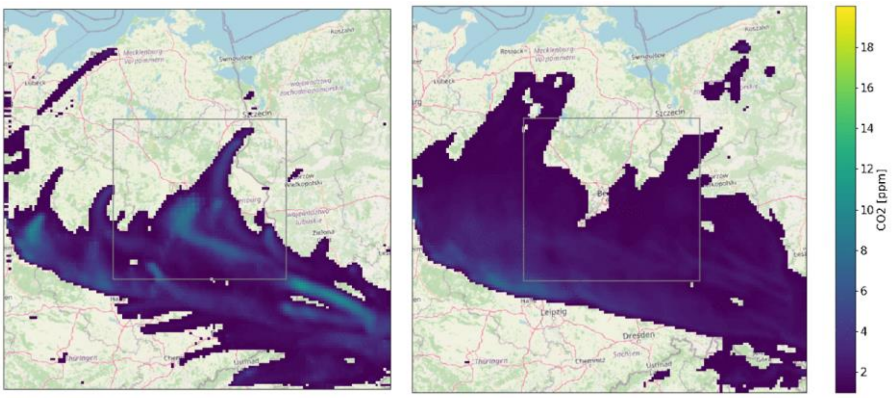

Figure 2 left) Anthropogenic CO_2 concentration enhancement field. right) biogenic CO_2 concentration enhancement field over Berlin for an exemplary time step in summer 2021. From Master thesis Leonie Kemeter

Towards inverting the concentration data, we have performed first backward trajectories with Flexpart-WRF for Berlin. We have currently found normalization issues, which we are further investigating together with the developers of WRF-Flexpart (https://www.flexpart.eu/ticket/329).

Attributing CO_2 variations observed in satellite records

Analyzing total column satellite measurements over Australia, we have seen end-of-the-year CO_2 peaks, which have not been reported so far using in-situ data. We were able to attribute these to rewetting processes in semi-arid areas (Mertz et al., 2023).

Complementary, we have analyzed the total column measurements by using the calculated footprints in conjunction with flux data. We were able to consistently reproduced the concentration results of the Carbon-Tracker CT2019B dataset. In a weekly inversion study of 15 Australian regions we found that the full seasonal cycle was predominantly present in the north-eastern regions of Australia, with the semi-arid regions having the greatest impact (see Figure 3). In general, most of the regions studied contributed to the end-of-year peak. Our inversions suggest that the exceptionally large peak in 2009 was mainly due to additional fluxes from sparsely vegetated regions. Our total monthly fluxes showed general agreement with the CO_2 fluxes based on the GOSAT inverse model TM5-4DVAR. We conclude that our approach, based on footprints of satellite measurements, shows good agreement with other methods and is a promising tool for estimating surface fluxes on a subcontinental scale, which is what we plan to conduct for Africa and South America in the next computation project at DKRZ.

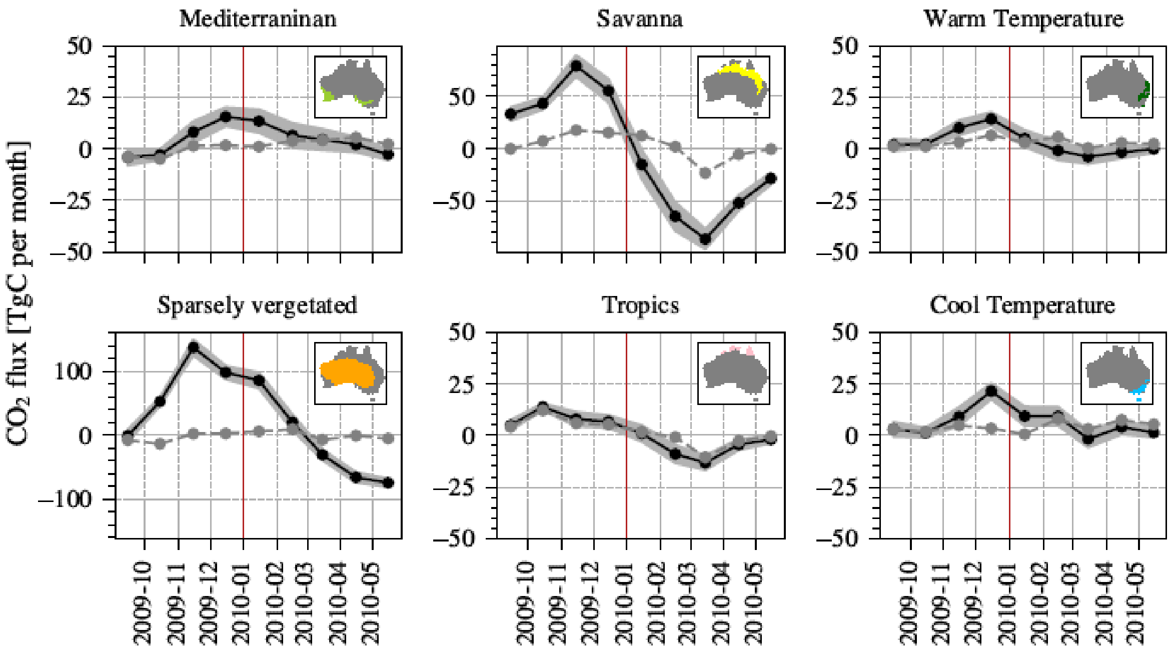

Figure 3: Monthly posterior (black) and prior fluxes (gray) per bioclimatic region. Uncertainties of posterior from posterior covariance are shown as gray halo. The turn of the year is marked by the red vertical line. From Master thesis Christopher Lüken-Winkels

Final remark:

We have decided against running the GRAMM/GRAL model (suggested WP2) at DKRZ and instead conducted the analysis on the in-house servers as there have been unplanned capacities on the in-house servers and the software was already set-up on the in-house cluster. We were therefore able to use the node hours for WP1 and 3.

References:

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