Project: **1170**

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

Principal investigator: **André Butz**

Report period: **2021-05-01 to 2022-04-30**

WP1 - Decadal data record of GOSAT and GOSAT-2

We have processed the GOSAT and GOSAT-2 decadal data record for the CO_2 and CH_4 column-average concentrations using our RemoTeC radiative transfer and retrieval code. Illustrative Figure 1 shows a time series of detrended CO_2 monthly-mean concentrations measured by GOSAT above the Australian continent, which will be one of our focal regions for data interpretation in the upcoming project period. Figure 1 compares the most recent processor version (GOSAT/RemoTeCv240) with the previous one (GOSAT/RemoTeCv238) and with a CO_2 inverse model (TM5-4DVar). The time series shows clear discrepancies between the satellite and the model data which we are in the process of examining in terms of attributing the differences to deficient representation of ecosystem processes.

For the processing, we used less than expected compute resources on Mistral, because we were able to use a larger share of our in-house resources (which were less booked than expected due to other projects being on hold because of the COVID-19 pandemic). Partially, the WP1 resources on Mistral were re-distributed to WP2 which required more than expected compute power. On Mistral, we typically reserved individual nodes and submitted 16 serial jobs in parallel to each node. Each of the jobs took close to 2h processing time with only small differences for each job. Thus, the speed-up scaled linearly and we were able to exhaust the resources of the allocated nodes to a good degree.

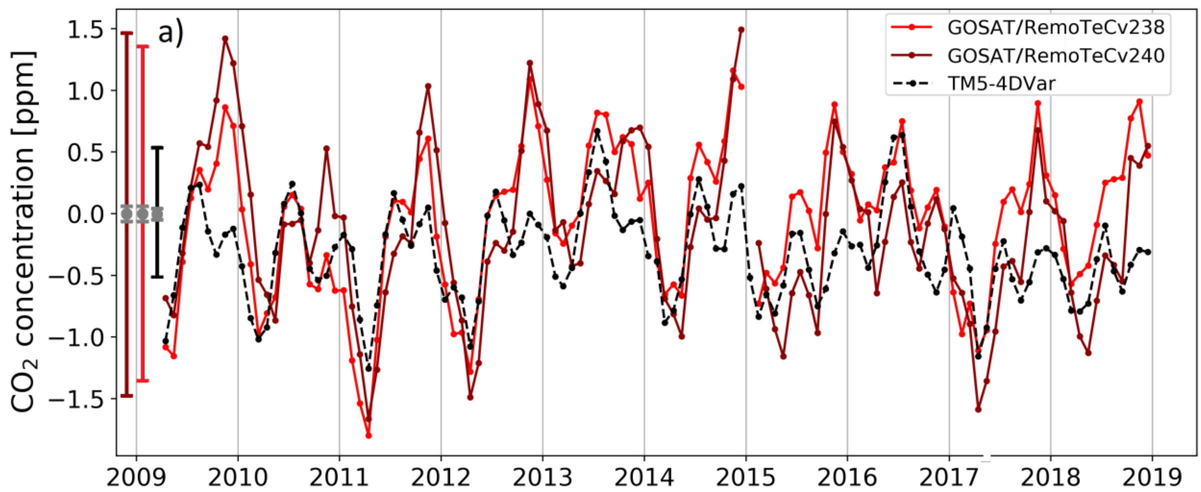

Figure 1: Detrended CO_2 column-average concentrations measured by GOSAT above Australia in the period 2009 to 2019.

WP2 - Weather research and Forecasting model (WRF) simulations on high resolution

We have set-up the WRF model for the Rhine-Neckar region on high-resolution (1km x1km). As a first step, we have performed an analysis of our WRF set-up to optimize the available computation resources with respect to nodes, used CPU and computation time. We found maximum performance with respect to parallel efficiency when compiled with distributed memory (pure OpenMPI) parallelism and run with one MPI task per physical core (cpus_per_task). The speed-up scales about linearly with number of total threads and node numbers, which will enable us to make even better use of Levante's resources as the number of physical processors per node is higher.

With these settings, we have simulated two 1-week periods of meteorological variables using various different model parametrizations and compared them to re-analyzed data from the European Centre for Medium-Range Weather Forecasts (ECMWF) and 17 selected measurement stations from the German Weather service (Fig. 2a-c). Thus, we evaluate the influence of different nudging and restart strategies as well as parameterizations of physical processes and urban interactions on the model performance of air temperature, wind direction, wind speed and boundary layer height (not shown here).

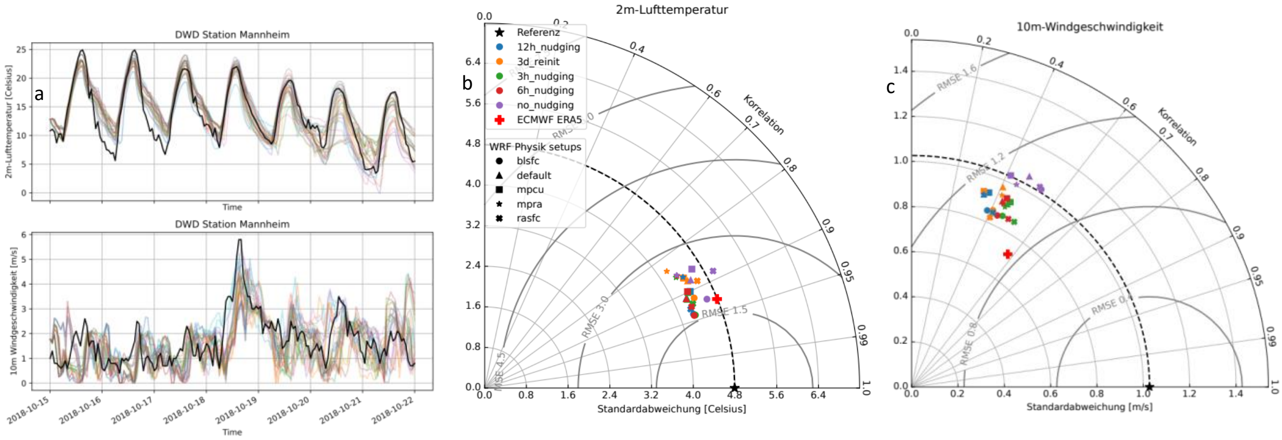

Figure 2: a) Exemplary period (15.10-22.20.2018) for analysis of temperature and wind speed. Black: Temperature and wind speed at a selected DWD station. Colors: WRF-Simulation results using different physics schemes. b) Taylor plots of temperature (2m) and c) wind speed (10m) for different WRF physics setups and nudging/restart options as well as ECMWF data for the same exemplary time period.

Simulations of temperature agreed very well with stations observations and showed high correlation coefficients of >0.95 and only slightly underestimating the variability of temperature change. Wind velocities showed a lower correlation coefficient of about 0.4 for the illustrated period, but correlations increase when absolute wind speeds are higher. Inspecting the agreement at individual stations, we found a good overall agreement of synoptic changes. In principle, we found that nudging improves the simulation-observation agreement. However, the nudging interval can be as low as 12 hours for equally good performance. The physics parametrization had a larger effect on model performance than the nudging frequency did, but a comparable one to the decision on whether or not to nudge at all. ECMWF results agreed similarly, or even better than WRF-simulations. However, this is expected and in agreement with the findings by Lian et al. (2018) for Paris, as the observation data is actually assimilated in the ECMWF data product. Interestingly, we found hardly any improvements in model-data agreement when using 1, 2 or 3 domains, which is most likely a result of the good match of ECMWF and station data and might be partially due to not sufficiently resolved input data in WRF, which we continue to optimize.

Altogether, we were able to obtain realistic meteorological simulation results using WRF on 1km, which is a prerequisite of analyzing greenhouse gas observation strategies in an OSSE as planned in the BMBF-project „Intergriertes Treibhausgas Monitoring System" (ITMS), which has launched in December 2022. The results of this simulation have been presented on the DACH conference 2022 (https://doi.org/10.5194/dach2022-69). Further, we plan on publishing the results this year.

References:

Lian, J. et al., (2018): Evaluation of the WRF-UCM mesoscale model and ECMWF global operational forecasts over the Paris region in the prospect of tracer atmospheric transport modeling.
doi: https://doi.org/10.1525/elementa.319