Project:	**1174**
Project title:	**Effects of Absorbing Aerosols on Cloud Cover over Germany**
Project lead:	**Dr. Fabian Senf (TROPOS)**
Allocation period:	**1.7.2022 - 30.6.2023**

Overview

The project is dedicated to the research question how the presence of absorbing aerosol such as black carbon changes the atmospheric state including clouds. Aerosol-mediated changes in the atmosphere occur at rather short time scales compared to other climatic changes, and thus appear to be mainly independent of near-surface temperature changes. Therefore, the changes in the atmospheric state due to aerosol absorption are assigned to the so-called rapid adjustments to aerosol-radiation interactions (ARI) - formerly known as semi-direct effects - which together with the direct (or instantaneous) radiative forcing of aerosol can be combined to the effective radiative forcing.

Resource Utilization

At the time this report was written, approximately 70% of the granted computing resources were being used by project members, while 30% expired unused. Resources were used by F. Senf (PI), one PhD student, three Master students and one Bachelor student. This also means that time was invested from our side to make the early career scientists familiar with the compute environment at DKRZ and to educate the next-generation scientists in HPC aspects. Thanks to the very easy to use interface to DKRZ Jupyterhub, an important part of the work and therefore used resources was put into the scientific analysis of the generated simulation data.

Scientific Results

The main work in the bb1174 project dealt with the question of how aerosols influence the adjustment processes in the cloudy atmosphere through their interaction with atmospheric radiation. For this, a scaling scheme was implemented in which the bulk aerosol absorption and the bulk aerosol scattering properties can be scaled by a certain weight via a namelist parameter. Due the change of the main supercomputing infrastructure from Mistral to Levante in 2022, a swift in ICON version from v2.6.3 to v2.6.5-rc and later to v2.6.5 needed to be done by us. To ensure consistency of our results, all aerosol perturbation runs with older ICON versions needed to be repeated and analyzed in depth for the new computing system and the new ICON versions. Fortunately, the same qualitative results were obtained. Furthermore, two different radiation schemes ECRAD and RRTM were tested extensively.

As part of a Master thesis, joint perturbations in aerosol scattering and aerosol absorption have been applied. The idea was to learn more about the different pathways, adjustments to aerosol-radiation interaction may take depending on how much the atmosphere is heating vs. how much shortwave radiant energy is lost at the surface due to the known surface dimming effect. In essence and shown in Fig. 1, we found that both process pathways (atmospheric heating vs. surface dimming) contribute

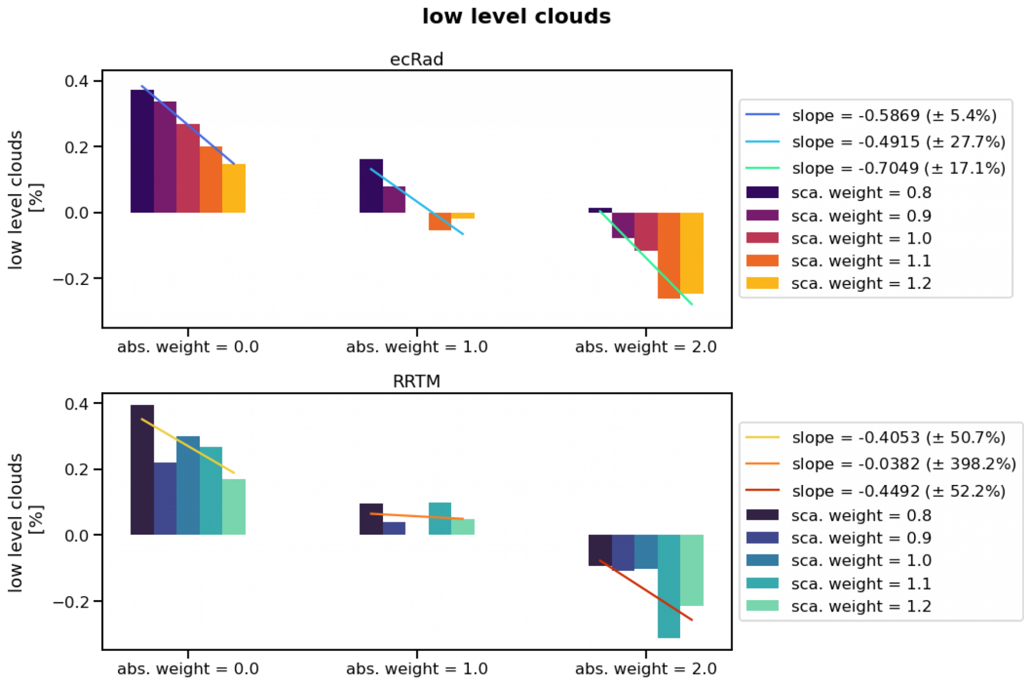

Figure 1: Domain- and time-averaged low-level cloud cover anomaly for different combinations of absorption weight (sections on the x-axis) and scattering weights (differently colored bars) and for different radiation schemes (upper vs. lower row). Least-squared regression results are indicated.

a portion to the earlier identified reduction in low-level cloud cover (Senf et al., 2021). These results are very motivating and will lead to further investigations on this topic.

The original project plan which was detailed in the project proposal involved to expand numerical study of the aerosol-radiation interactions towards more different meteorological cases. However, when we started to conduct this extension in the frame of the bb1174 project, a bug in ICON came to light that was important for our calculations and which leads to strong and unrealistic fluctuations in the vertical profiles of the analyzed anomalies. This becomes especially apparent for temperature. For this reason, and to save resources, the extension of the simulations has been postponed until the cause of the bug found has been fixed. We currently assume that implementation within the LEM turbulence description is faulty. This will be investigated in the next allocation period. After the bug is fixed, we will return to our original plan and run the simulations for different case days.

The project bb1174 provided an environment to support other, not originally planned work, for which we are grateful: student work on Australian wildfire effects (Müller, 2022), student work on cloud classification problem using modern ML-based techniques (Weigert, 2022) and support for BMBF proposal preparations.

References

Müller, J., 2022: Global Adjustments and Circulation Responses to Smoke Aerosol Forcing from Australian Wildfires, Masterarbeit. Masterthesis, University of Leipzig.

Senf, F., J. Quaas, and I. Tegen, 2021: Absorbing aerosol decreases cloud cover in cloud-resolving simulations over Germany. *Quart. J. Roy. Meteor. Soc.*, **147 (741)**, 4083–4100, doi:https://doi.org/10.1002/qj.4169, URL https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/qj.4169, https://rmets.onlinelibrary.wiley.com/doi/pdf/10.1002/qj.4169.

Weigert, H., 2022: Non-Parametric Supervised Machine Learning for Classification and Analysis of Simulated Cloud Distributions. Masterthesis, University of Leipzig.