Project: **1393**

Project title: **Global aerosol modelling for transport and aviation research**

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Report period: **2023-11-01 to 2024-10-31**

The planned scientific work in Project 1393 during 2024 focused on five main scientific topics. Due the significant reduction on the requested resources (53% for CPU), only a subset of the planned simulations could be performed. Details about each of the targeted topics are summarized in the respective sections below.

1. Aviation-aerosol impact on clouds

The EMAC (MADE3) simulations planned to refine the estimates on the aviation impact on low clouds based on a recently developed double-box plume model could not be performed. The reason is that an unexpectedly large sensitivity of the plume model results to the initial meteorological parameters was found, in particular on temperature and relative humidity, with a significant impact the aerosol nucleation process. These results were originally planned to be used to drive the initialisation of the aviation emissions in EMAC (MADE3) simulations, especially concerning the aerosol particle number. To derive a more robust parameter assessment, the plume model had to be further refined and ensemble plume model simulations had to be performed, with varying background conditions representative of different regions of the world. Although the plume model runs on a single CPU with a negligible amount of resources, several hundreds of plume model simulations were required to cover each region with an ensemble approach. This implied a significant time investment during the reporting period for the data analysis and delayed the planned full-scale simulations with EMAC (MADE3). The plume model is currently being documented in a paper (Sharma et al., in prep. for Geosci. Model Devel.) and it is also the subject of a PhD Thesis to be submitted by the end of the year.

The resources originally allocated to study the aviation impact on low clouds have been instead used for a follow-up study on the Righi et al. (2021) assessment on the aviation-soot impact on natural cirrus clouds. Thanks to a collaboration with the ETH Zurich, new estimates on the ice nucleation abilities of aviation soot were made available from laboratory measurements behind aircraft turbines (Testa et al. 2024a,b) and used to drive EMAC (MADE3) simulations. A set of simulations have been performed driving the cirrus parametrisation in the model with these new parameters and further exploring the sensitivity of the results to the properties of other ice nucleating particles competing with aviation soot for available supersaturation (namely, soot from background sources, mineral dust and ammonium sulfate). The results are currently being summarized in a paper (Righi et al., in prep. for Environ. Res. Letters.).

2. Global aerosol dataset in support of life-cycle modelling for aircraft engines

In the context of the BMWi-LuFo-V-3-Projekt DoEfS (*Digitally optimized Engineering for Services*) a global highly-resolved atmospheric dataset has been generated with the EMAC (MADE3) model and used by Rolls-Royce Deutschland as a basis to model the impact of atmospheric aerosol and other environmental factors on the wearing and corrosion of aircraft engines. In the follow-up project DiSTAnS (*Digital Service Twin for Aeroengines and electrified propulsion Systems*) an extension of the dataset to more recent years is planned.

During the last reporting period, data for 2021 and 2022 simulated with EMAC (MADE3) have been provided to Rolls-Royce Deutschland. This consists of a temporally highly-resolved model output at 1h resolution for a selected subset of 44 variables, including meteorological parameters and volume mixing ratios of tracer gases and aerosol. The dataset will be further extended during the next allocation period and complemented with an advanced statistical analysis of the data based on the clustering method developed by our group, which should enable a significant reduction of the data burden by clustering the data in specific regimes over different regions and altitude ranges, based on the properties of the aerosol particles in these regions. These methods are based on Li et al. (2022) and have been further extended in the recently published work by Li et al. (2024), where we also showed their applicability to different scenarios and a refinement with a sub-classification method over selected regions.

3. Impact of ice nucleating particles on cirrus cloud properties

In the context of the DLR project MABAK (*Innovative Methoden zur Analyse und Bewertung von Veränderungen der Atmosphäre und des Klimasystems*) several global model simulations have been performed in order to analyse aerosol-cloud interactions by combining model results with satellite, in situ, and lidar measurements. In this project, the EMAC model including the MADE3 aerosol microphysics sub-model coupled with a two-moment cloud scheme, has been applied, employing a model setup based on Beer et al. (2024). For the combined analysis of model data with satellite measurements data from the IASI instrument (*Infrared Atmospheric Sounding Interferometer*) aboard the MetOp (*Meteorological Operational*) satellite has been used to analyse the impact of Saharan mineral dust particles on cirrus clouds. For the combination of model results with lidar and in situ data dedicated simulations targeting the episodes of the HALO (*High Altitude and Long-Range Research*

Aircraft) measurement campaigns ML-CIRRUS and CIRRUS-HL have been performed to investigate the impact of aerosol particles on cirrus clouds at mid and high northern latitudes. The EMAC simulations performed for this project will also be part of two PhD theses.

4. Process-level understanding of aerosol-cloud interactions in liquid-phase clouds

Due to the reduction in the applied resources, no further simulations have been conducted on this subject during the reporting period. Simulations performed in earlier phases of DKRZ Project 80 have been analysed instead. In particular, a comparison between EMAC (MADE3) model simulations and ACTIVATE (*Aerosol Cloud meTeorology Interactions oVer the western ATlantic Experiment*) in situ measurements has been performed. This analysis showed that cloud droplet number concentration in marine clouds agrees simulated by EMAC agrees well with observations on a climatological basis and that the model captures the dependency of CDNC on vertical velocity as well as the impact of different aerosol loads on cloud droplet number concentration in marine clouds. However, the model overestimates liquid water content, underestimates aerosol numbers, and underestimates the variability in cloud droplet number concentration for low marine clouds in the planetary boundary layer. The latter is related to the implicit assumptions about particle aging at unresolved scales below the gridbox size (~300 km). To improve on these biases further analysis will be required, also involving additional data to cover other regions.

5. Improved representation of secondary organic aerosol particles

The planned simulations could not be conducted due to the reduction in the applied resources. The topic is however still relevant and the corresponding resources will be applied again for in the next round of proposal.

6. Representation of particles from non-exhaust transport emissions

The planned simulations could not be conducted due to the reduction in the applied resources.

References

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