Project: **1143**
Project title: **FORCES**
Principal investigator: **Johannes Quaas**
Report period: **2025-11-01 to 2026-10-31**

CleanCloud is the follow-up EU-funded project that followed the FORCES project. In the reporting period, the focus was on its work package WP8, dealing with the preparation of case studies on the impact of aerosols on convection, the preparation of forward simulators for comparison to satellite data, and on the perturbed-parameter ensemble.

During the reporting period of 2025-11-01 to 2026-10-31, the coupling between the simplified aerosol module, HAM-lite (Weiss et al., 2025), and the two-moment cloud microphysics scheme (Seifert-Beheng scheme) of ICON has been further developed. The influence of sub-grid scale turbulent fluctuations on aerosol activation is incorporated as per Ghan et al., 1997. In order to improve the representation of aerosol processing by clouds and their regeneration upon cloud evaporation, tracers for non-interstitial aerosols for each mode have been implemented. Along with the implementation of a more-detailed wet deposition scheme which explicitly accounts for the microphysical process rates, this yields more realistic cloud-droplet number concentrations when compared with aircraft observations during the ORCESTRA campaign (https://orcestra-campaign.org/intro.html). Limited-area aerosol perturbation runs with present-day (PD) aerosol emissions and with anthropogenic emissions reduced by a factor of 3 (named pre-industrial, PI) conducted during the period of the ORCESTRA campaign (Aug 08 - Sept 09, 2024) at R2B9 (~ 5km) horizontal resolution, yield a significant change in the net cloud radiative effect of -5 W m^{-2} (see Fig. 1(a)). Preprints on the benchmarking of the latest developments with ground-based and EarthCARE observations during ORCESTRA, and a detailed analysis of the modifications to the underlying cloud microphysical processes and the background environment which yields the change in cloud radiative effect in response to aerosol perturbations, are in preparation and will be submitted soon. A comparison between month-long (Aug 01 - Aug 31, 2024) global test runs at R2B8 (~10 km) resolution with PD and PI aerosol emission levels also yields a large net cloud radiative effect of -2.5 W m^{-2} (Fig. 1(b)). Further investigation and analysis of this, and longer global simulations at higher resolutions will be undertaken in the next allocation period.

We made good progress in the CAFE-Brazil exploration of aerosol impacts on convection in the Amazon region. Project scientist Alice Henkes leads a model intercomparison study together with multiple international partners and conducted the ICON simulations herself. An international project meeting on this is planned for early November, and a publication is expected to be drafted soon thereafter, with Henkes as lead author.

The study on generating the perturbed parameter ensemble (PPE) made relevant progress in the reporting period, too, although not yet leading to tangible results. The results for many different regional limited-area studies, perturbing multiple cloud parameters, yielded significant problems. On the one hand, the model showed large systematic deficiencies in comparison to the targeted CERES observations of the Earth radiation budget. On the other hand, these model results showed only very little sensitivity to the perturbations of the parameters. Fortunately, in September, this problem could finally be overcome. It had to do with problematic parameterisation choices. Subgrid-scale rather than grid-scale cloud cover was chosen, which hampered sensitivity and skill. Now with the “all-or-nothing” scheme at the high resolution, the model at the same time is better in comparison to observations and more sensitive to parameter settings. Further progress was achieved by making use of interactive calculation of cloud droplet effective radii. This now allows us to return to the original plan, which we propose to continue in the following allocation period.

References

Weiss, P., Herbert, R., and Stier, P.: ICON-HAM-lite 1.0: simulating the Earth system with interactive aerosols at kilometer scales, Geosci. Model Dev., 18, 3877–3894, https://doi.org/10.5194/gmd-18-3877-2025, 2025.

Figures

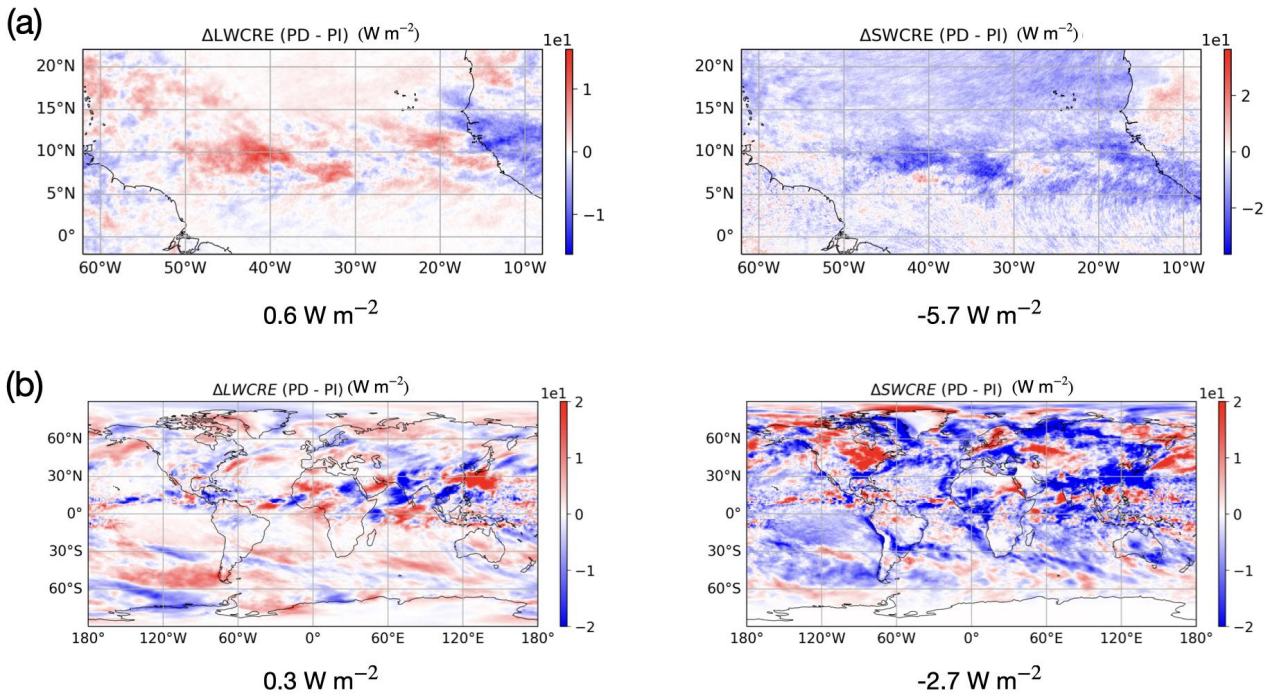


Fig. 1: (a) Change in time-avergaged long wave (LWCRE) and short wave (SWCRE) cloud radiative effects between the limited-area ORCESTRA domain runs with PD and PI aerosol emissions; (b) the same for the coarser-resolution global runs. The values at the bottom of each sub-figure is change in domain-and-time-averaged cloud radiative effect.

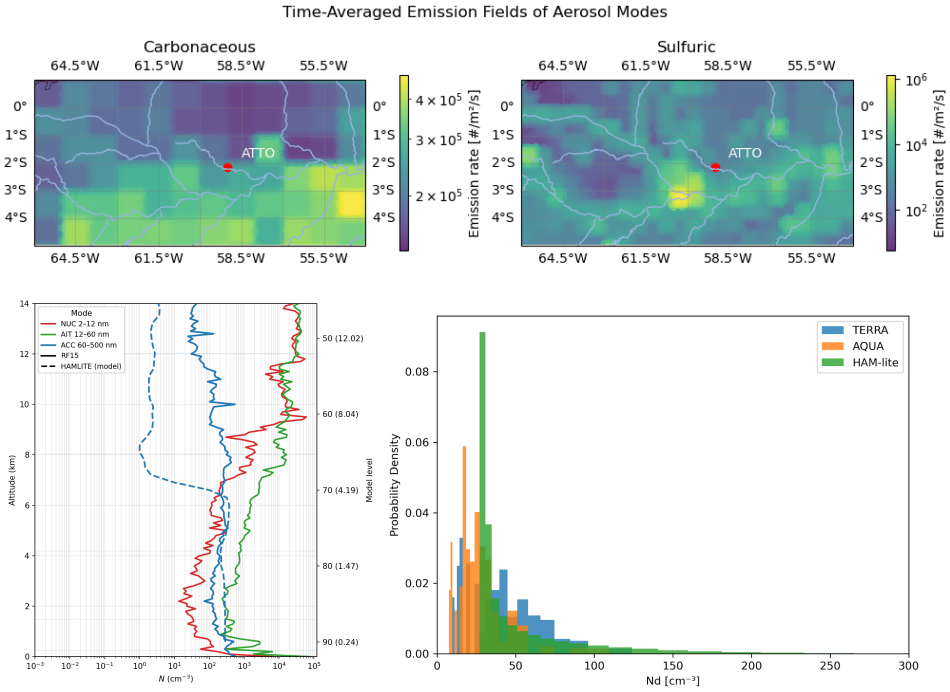


Figure 2. Spatial distribution of carbonaceous and sulfuric aerosol emissions over the Amazon region (upper panel). The lower-left panel shows aerosol number concentration profiles from HALO flight observations and from HAMlite, while the lower-right panel compares simulated cloud droplet number concentrations with estimates from MODIS.