Project: **1143**
Project title: **FORCES**
Principal investigator: **Johannes Quaas**
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CleanCloud is the follow-up EU-funded project that followed the FORCES project. In the reporting period, the focus was on its work package WP7, dealing with the preparation of case studies on the impact of aerosol on convection, on the preparation of forward simulators for the comparison to satellite data, and on the perturbed-parameter ensemble.

In line with the request last year, we have performed a few runs with a limited-area setup of ICON-HAM-lite (Weiss et al., 2025) as part of the EarthCare-ORCESTRA Model Intercomparison Project (https://www.earthcarescience.net/projects/ecomip). The interactive aerosol module HAM-lite coupled to ICON via the AES physics parameterizations was set up over a limited-area domain encompassing the Atlantic ITCZ as part of the EarthCare-ORCESTRA Model Intercomparison Project (ECOMIP). As a part of the MIP, month-long simulations were run with one-moment cloud microphysics for August 2024 at 5km horizontal resolution. CEDS and GFAS emission datasets were used for the forcing of the anthropogenic and wildfire emissions, respectively. Aerosol burdens displayed in Fig. 1a clearly capture the fine-scale structures of the Saharan dust storms (“haboobs”) and sea-salt emissions over along the ITCZ, and the advection of the anthropogenic aerosol species. A clear signal is visible in the difference between the cloud radiative effects of the reference run and that with no anthropogenic and reduced wildfire emissions (Fig. 1b). This highlights the importance of km-scale simulations with GCM’s to accurately quantify aerosol-cloud interactions. Constraining the aerosol module with data collected from the ORCESTRA campaign is in progress.

The second case explored was the Amazon region, linked to the CAFE-Brazil field campaign. For the case study preparation using ICON with the HAMlite aerosol module (Weiss et al., 2025), we explored the Amazon region under different conditions relative to the default configuration (Figure 2): from the empirically pristine rainforest, long-range transport (LRT), and mixed-pollution regimes (Pöhlker et al., 2018). Accurately representing aerosol number concentrations is essential, since the configuration of aerosol modes strongly influences cloud droplet number concentration and subsequent precipitation processes. To compare the modeled aerosol profiles with HALO observations, we examined the aerosol setup in the regional HAMlite configuration (Kubin et al., 2025) at R2B09 grid resolution, and also tested the impact of increased resolution with R2B10.

The study on generating the perturbed parameter ensemble (PPE) is ongoing. We have selected the key parameters and generated the sets of input parameters using Latin Hypercube Sampling. The processes to be tested, as defined earlier, are updraft variance, secondary ice production, and liquid and solid formation. We have not yet completed all PPE simulations because the regional configuration is still under development. This includes the implementation of the two-moment cloud microphysics scheme by the Oxford team, which will allow us to explore the secondary ice production using the new developments. A specific task was on exploring the cloud droplet activation in ICON-HAM: sensitivity of cloud droplet activation in the Lohmann scheme by changing its empirical coefficients. The Lin and Leaitch (1997) cloud droplet activation parameterization, implemented in ICON-HAM, empirically relates the number of activated cloud droplets to aerosol number concentration and updraft velocity. The original fit was derived from aerosol and cloud droplet measurements collected during a North Atlantic field study. Here, we test alternative fit parameters (A, b_1, and b_2), derived using total aerosol particle measurements from ATTO and additional datasets available in the literature. After replacing the original coefficients from Lohmann et al. (2007), we perform a five-year simulation to assess the sensitivity of the model’s climate forcing to these parameter changes. Subsequently, we will run preindustrial (PI) and present-day (PD) simulations using both the original and the fitted Lin–Leaitch schemes to estimate the associated radiative forcing. The final choice for the new fit parameter is defined by the activation vertical velocity range from the ICON-HAM.

References

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Figures

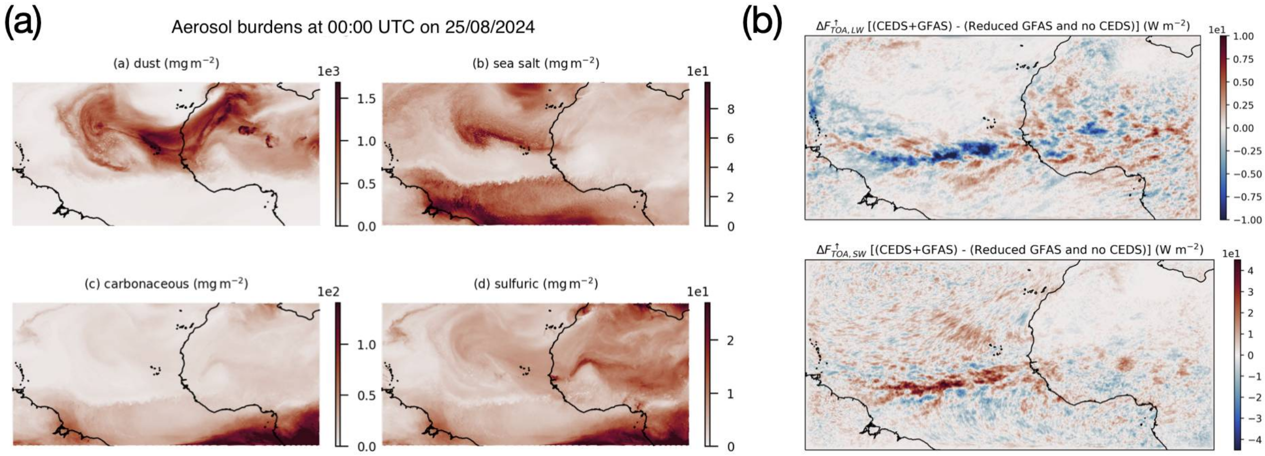

Fig. 1: (a) Instantaneous burdens of the aerosol mode – dust, sea-salt, carbonaceous, and sulfuric species – in ICON-HAM-lite. (b) Difference between the top-of-the-atmosphere longwave (top) and shortwave (bottom) radiative fluxes emitted by the clouds between the reference run and, that without anthropogenic emission forcing and reduced wildfire emissions.

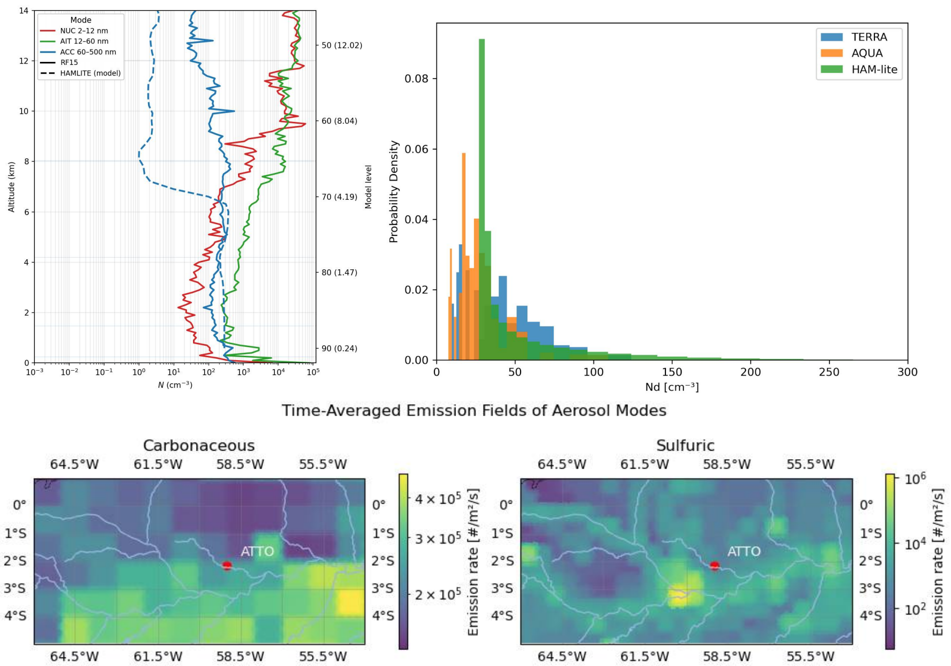

Figure 2. Spatial distribution of carbonaceous and sulfuric aerosol emissions over the Amazon region (upper panel). The lower-left panel shows aerosol number concentration profiles from HALO flight observations and from HAMlite, while the lower-right panel compares simulated cloud droplet number concentrations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