Project: **893**

Project title: **Convection and Clouds in Earth System Modelling**

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Report period: **2025-11-01 to 2026-10-31**

In the current allocation period, not all the computing resources have been utilised on Levante. This was a consequence of the limited data storage capacities. As on the work disks a substantial amount of data for a manuscript, that has just been submitted in the beginning of October 2026 has been stored, the amount of calculations and data to be generated was limited. Another limitation has been set that the data from this simulation could not be stored on the tape archive, as the amount of archive space has also been too limited. Furthermore, the PhD candidates in the CRC TPChange only started in the second half of 2026, such that the computing resources could not fully be used before July. We are planning to use the remainder of the resources for the planned project as outlined in the request for 2026.

The major calculations done in this application period focussed on the calculation of aerosol optical properties in the framework of the development of the new AOP (aerosol optical properties) submodel within the MESSy interface structure. Corresponding global multi-year simulations with the ECHAm5/MESSy Atmospheric Chemistry (EMAC) model have been conducted and the data has been post-processed and visualised. The focus of this research study has been on the direct aerosol-radiation interactions in the upper troposphere (UT). In a first step the contribution of the UT extinction to the total extinction has been quantified using an interactive aerosol scheme (Fig.1).

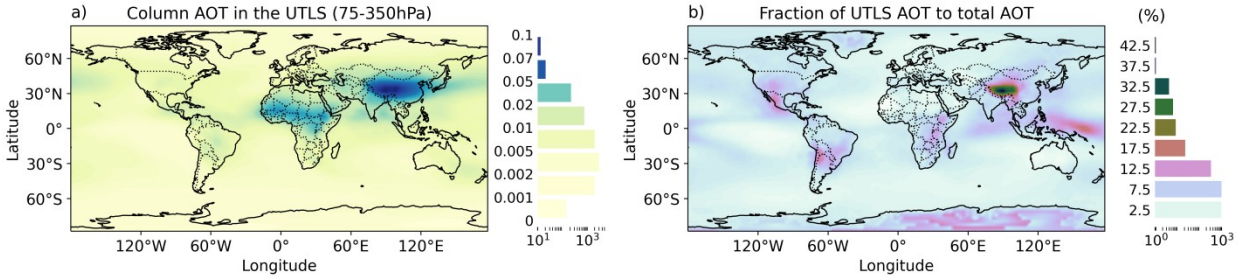


Figure 1: Total Aerosol extinction in the UT and fraction of the UT AOT to the total AOT.

It is shown, that the UT contributes in many regions to more than 10% of the total extinction; note also the frequency of occurrence displayed in the color bars. Specific regions are the Tibetan plateau and the Sahel-zone. The first one is characterised by the high elevation such that transport of near surface area to the UT is faster and that the whole tropospheric column is more compressed in this region, the latter is subject to substantial dust load. However, only the Tibetan plateau represents a substantial fraction of the total extinction, whereas the elevated UT extinction in the Sahel is only a minor contributor to the total column AOT due to the high near surface extinction. Secondly, the most important compounds contributing to the UT extinction have been determined (see Fig.2). The most important component is aerosol water, followed by dissolved inorganic ions. In certain regions, mostly close to the dust source regions, also mineral dust plays an important role for the UT extinction.

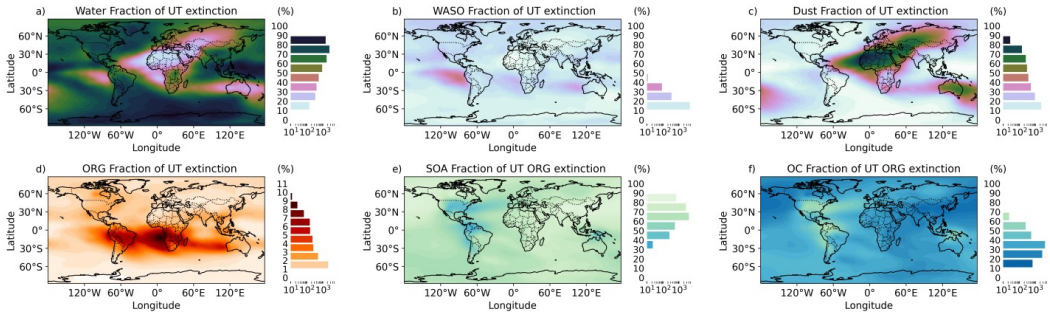


Figure 2: Fractional contributions of individual radiatively active aerosol compounds in to the total UT extinction.

Organics and black carbon are minor contributors to the UT aerosol extinction.

In the same framework scaling experiments for the UT extinction have been conducted to analyse the effect of UT extinction on the Earth's radiation budget. For that purpose the extinction between 350 and 80 hPa has been re-scaled using scaling factors of 0.6, 0.9, 1.1, 1.4, and 2.0, respectively. The impact of those re-scaled extinction on the radiation fluxes and the surface temperature heating rates are analysed. It is shown in Fig.3, depicting that e.g., a doubling of the UT extinction leads to a disturbance of around -80 mW/m² at the surface and even stronger effects in the upper troposphere. Similarly, a reduction of the extinction by 40% results in a flux disturbance of 25 mW/m². Consequently, those disturbances are of similar magnitude as e.g., aircraft emissions or contrails.

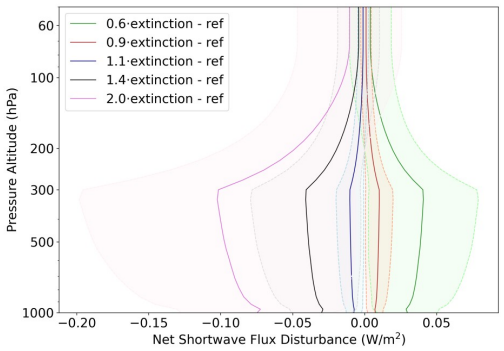


Figure 3: Net shortwave radiative flux disturbance from the UT extinction scaling experiments.

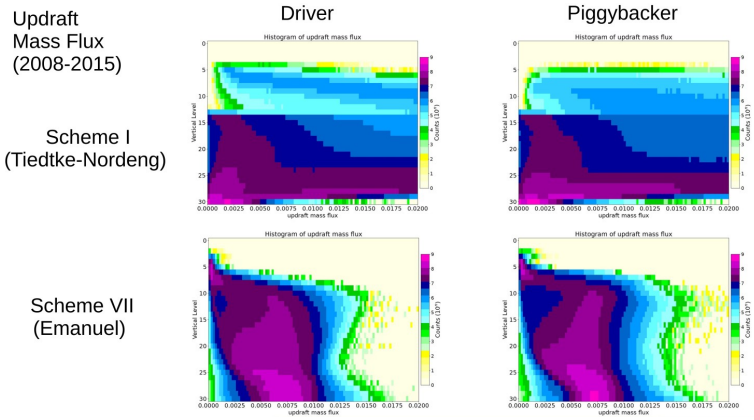


Figure 4: Convective updraft massflux frequency distributions with piggybacking.

In WP IV of the proposal, the goal was to implement and run different convection schemes in parallel using a "piggybacking" approach, i.e., the same driving meteorology is forcing different convection parame-terisations. This is depicted in Fig.4, showing the Tiedtke-Nordeng and the Emanuel convection schemes run in parallel, once as the driver and once as the piggybacker from two different simulations. The shown quantity is the frequency distribution of the updraft mass flux from both schemes. Not only it can be seen that the two schemes show distinct differences, especially in the upper levels, i.e., the UTLS region, but also that there are more subtle differences originating from the meteorological forcing.

Beyond those two WPs which have directly been addressed, test simulations for WP II have been conducted at DKRZ and are compared with the results of local computing resources at the JGU Mainz. Additionally, the configuration for the simulations in WP III has been finalised, such that those simulations are also starting. An example for the precipitation distribution over South America is shown in Fig.5 for the CAFE-Brazil configuration. Utilising the high resolution model COSMO, coupled with EMAC to generate the coupled MECO(n) system with several nests down to convection permitting resolution of a few km, the precipitation shows a clear signal of a mesoscale convective system or multiple organised convective cells over Brazil. The next nests will result in convection permitting scales, such that in this nest the parameterisation for deep convection will be turned off. At the moment, tuning simulations for the lightning frequency over South America are conducted to properly determine lightning NOx emissions suitable for comparison with the CAFE-Brazil research flights.

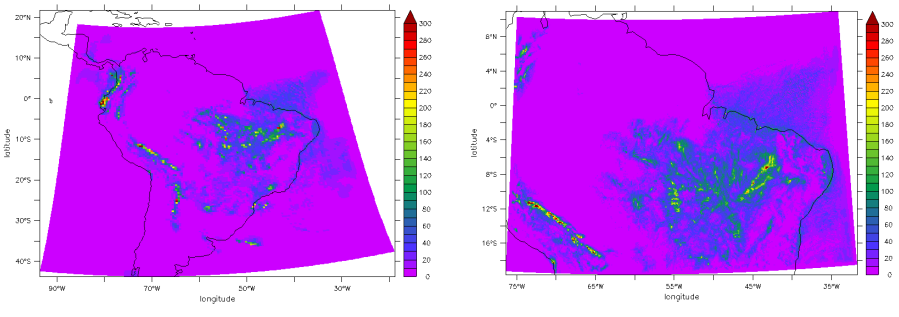


Figure 5: Precipitation patterns for a research flight over South America in nests 2 and three, i.e., 0.4° and 0.11° resolution.