Project: **883**
Project title: **Modelling of Saharan mineral dust**
Project lead: **Bernd Heinold**
Report period: **1.1.2025–31.12.2025**

Progress Report

The central aim of this DKRZ project is to evaluate and continuously improve the representation of mineral dust in the HAMMOZ model family: the global aerosol-climate model ECHAM6.3-HAM2.3 (Tegen et al., 2019), its successor ICON(MPI-M)-HAM2.3 (Salzmann et al., 2021), and the km-scale ICON-HAM-lite (Weiss et al., 2025). The 2025 allocation period was mainly dedicated to further developing and testing the new limited-area version of ICON-HAM-lite, with particular attention given to simulating mineral dust and its interactions with other aerosol species.

As part of the EU Horizon 2020 project nextGEMS, a version of the ICON-MPI Earth System Model was developed for regional to global storm-resolving simulations. ICON-MPI is coupled to the reduced-complexity aerosol module HAM-lite for km-scale interactive aerosol-climate simulations (Weiss et al., 2025). While based on the full and complex HAM module (Stier et al., 2005), HAM-lite represents aerosols as an ensemble of log-normal modes with prescribed sizes and compositions. The default configuration includes two pure modes – one for dust and one for sea salt – and two internally mixed modes containing organic carbon, black carbon, and sulfate. TROPOS recently developed a limited-area mode (LAM) version that enables targeted regional simulations while ensuring full consistency with the global model.

In 2025, ICON-HAM-lite LAM was applied to several case studies. A particular focus was on the 2019/2020 Australian Black Summer event, capturing the simultaneous emission and transport of desert dust and wildfire smoke. The simulations were performed using a R2B10 grid with 2.5 km horizontal spacing. Rectangular domains were defined to encompass the spatial extent of relevant aerosol processes, with the Australian domain spanning 132°E–160°E and 19°S–42°S, covering 25–31 December 2019. Sea surface temperature and sea ice were used as lower boundary conditions from AMIP, while initial and lateral boundary conditions for the atmosphere and land were prescribed from the operational analysis of ECMWF. The modeling results highlight the occurrence of intense dust activity triggered by frontal passages and moist convection across the continental inland. These mineral dust plumes were transported southeastward, interacting with bushfire smoke over southeastern Australia and the adjacent ocean as shown in Figure 1.

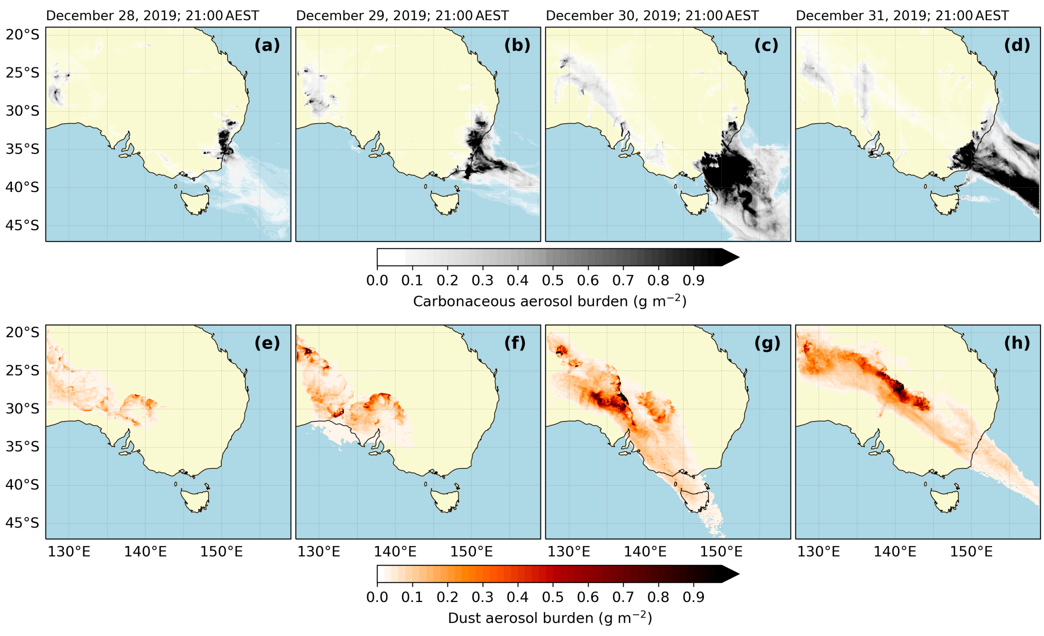

***Figure 1**: Maps of column burdens of carbonaceous aerosol (a-d) and desert dust (e-h) over south-eastern Australia and the southwestern Pacific Ocean on 28–31 December 2019, simulated with ICON-HAM-lite.*

The vertical structure of desert dust (Fig. 2) reveals that concentrations were generally confined to the lower and middle troposphere, with peak altitudes around 3–4 km. This contrasts with the coexisting carbonaceous aerosols, which extended into the upper troposphere and lower stratosphere through pyro-convective injection. Overall, the simulations show that desert dust played a notable yet localized role during the Australian Black Summer event. The simultaneous transport of desert dust in this case adds to the complexity of aerosol layering and potential radiative interactions, which will be investigated in future studies.

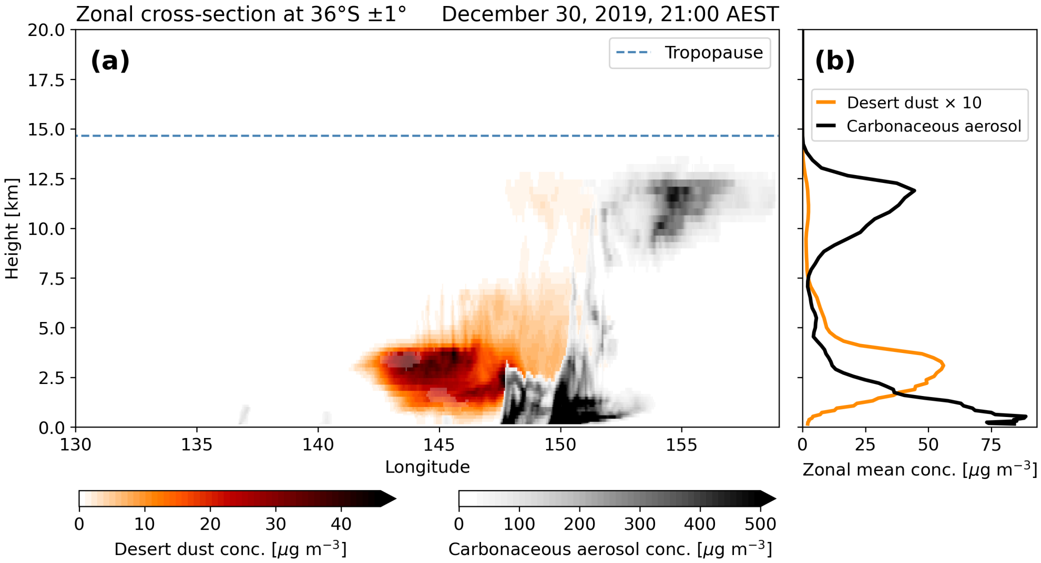

***Figure 2**: (a) Zonal cross section of aerosol concentrations along 36°S ± 1° latitude on December 30, 2019. Desert dust shown as coloured shading and carbonaceous aerosol from bushfires in grayscale. (b) Corresponding zonal-mean vertical profiles. The horizontal dashed line denotes the tropopause height.*

Perspectives

In 2026, further regional dust simulations and evaluations are planned for other major dust source regions, e.g., Northern Africa and Central Asia. This will also include work on desert dust–cloud interactions. In addition, the LAM functionality will be extended to the full HAM aerosol module in ICON(MPI-M)-HAM2.3.

Utilisation and Publication

These and additional evaluation results of the LAM version of ICON-HAM-lite will be published soon in *Heinold et al.* in *Geoscientific Model Development*, including a detailed description of the model setup and the LAM approach. All model developments and required input data are made available to the scientific community through the HAMMOZ website and repository (https://redmine.hammoz.ethz.ch).

References

Salzmann M., et al.: The global atmosphere-aerosol model ICON-A-HAM2.3 – Initial model evaluation and effects of radiation balance tuning on aerosol optical thickness, J. Adv. Model. Earth Syst., 2021.

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Tegen, I., et al.: The global aerosol–climate model ECHAM6.3–HAM2.3 – Part 1: Aerosol evaluation, Geosci. Model Dev., 12, 1643–1677, 2019.

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.