Project: **883**

Project title: **Modelling of Saharan mineral dust**

Project lead: **Bernd Heinold**

Report period: **1.1.2026–31.12.2026**

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 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. Within the present HPC project, Heinold and co-workers developed and applied the limited-area mode (LAM) configuration of ICON-HAM-lite, enabling targeted regional simulations fully consistent with the global model. This work resulted in the publication by Heinold et al. (2026).

The computing resources allocated to this project supported several aerosol-related case studies presented in Heinold et al. (2026), including simulations of the 2019/2020 Australian Black Summer event, characterized by the simultaneous emission and transport of desert dust and wildfire smoke. The Australian simulation employed a 2.5 km horizontal grid spacing over a domain spanning 132° E–160° E and 19° S–42° S for 25–31 December 2019. Sea surface temperature and sea ice were prescribed from AMIP, while atmospheric and land initial and lateral boundary conditions were derived from ECMWF operational analyses.

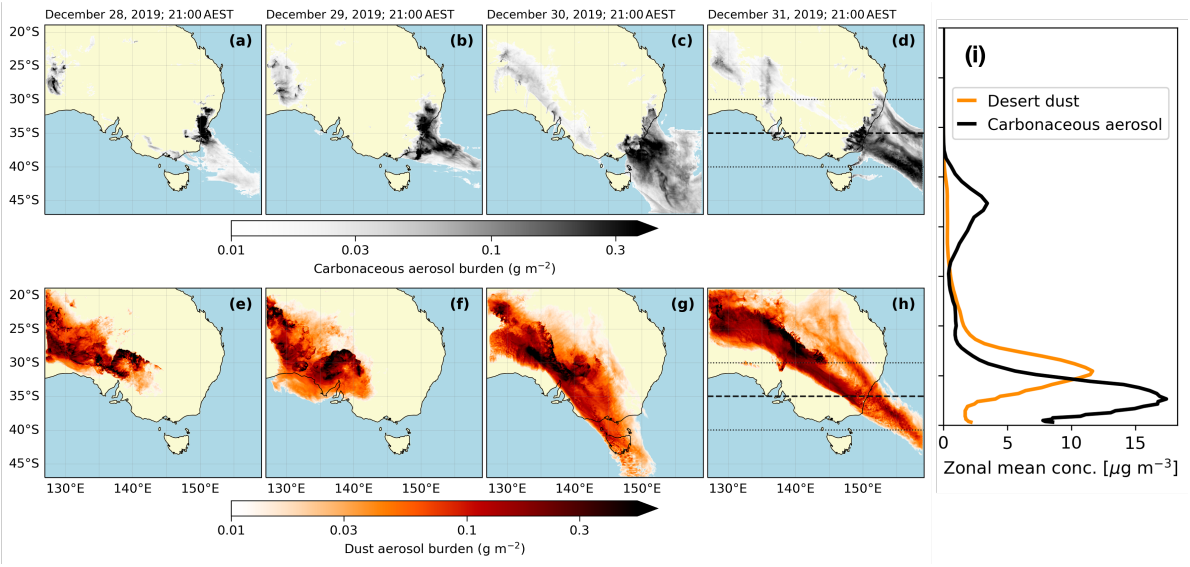


***Figure 1**: Maps of column burdens of carbonaceous aerosol (a-d) and desert dust (e-h) over south-eastern Australia and the southwestern Pacific Ocean on 28–31 December 2019, simulated with ICON-HAM-lite. (i) Corresponding zonal-mean vertical profiles averaged over the 5°-wide latitude band 35° ± 5° latitude on 31 December 2019.*

The simulations revealed intense dust activity over central Australia, with dust plumes transported south-eastward and interacting with bushfire smoke over southeastern Australia and adjacent oceanic regions (Fig. 1a–h). Dust was largely confined below 6 km, peaking around 2.5 km, whereas carbonaceous aerosols showed a bimodal vertical layering, with elevated smoke reaching the upper troposphere and lower stratosphere through pyro-convective injection (Fig. 1i).

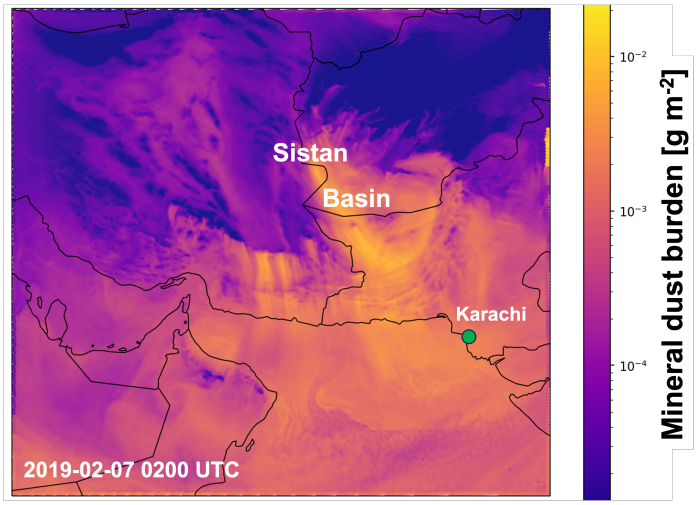


***Figure 2**: Initial preliminary ICON-HAM-lite modelling results on the atmospheric burden of a dust storm in the Sistan Basin in south-east Central Asia on 7 February 2019.*

In addition, a new case study has been initiated using a 2.5-km LAM setup of ICON-HAM-lite to investigate the drivers of mineral dust emissions in the Sistan Basin, located along the border between Afghanistan and Iran, and the subsequent long-range transport of dust towards the Arabian Sea. The study aims to assess the impacts of dust outbreaks on air quality and climate in surrounding countries and to explore potential strategies for mitigating extreme dust events. Initial ICON-HAM-lite simulations of a dust storm on 7 February 2019 reveal substantial dust emissions from the Sistan Basin and extensive transport of mineral dust towards the Arabian Sea (Fig. 2).

A substantial fraction of the allocated CPU node-hours remained unused during the reporting period, mainly because the computationally demanding ICON-HAM-lite simulations progressed more slowly than anticipated. Considerable effort was devoted to model debugging, testing, and evaluation using a limited number of simulations rather than conducting the originally planned series of sensitivity experiments. This work has helped establish the basis for more systematic simulations in the next allocation period, with a stronger focus on predefined research activities and efficient resource utilization. In addition, efforts are being made to transfer completed simulation and input data from the work file system to archive storage, addressing previous recommendations and reducing the demand for working storage.

Perspectives

Further regional dust simulations and evaluations for Central Asia are planned for 2027, in particular model experiments on source attribution. Saharan dust is being investigated with regard to its interactions with ice clouds, so-called ‘dusty cirrus’. In addition, the LAM functionality will be extended to the full HAM aerosol module in ICON(MPI-M)-HAM2.3.

Utilisation and Publication

The results of the LAM version of ICON-HAM-lite was published by *Heinold et al.* (2026), including a detailed description of 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

Heinold, B., et al.: ICON coupled to HAM-lite 1.0 in limited-area mode: an efficient framework for targeted kilometer-scale simulations with interactive aerosols, Geosci. Model Dev., 19, 6167–6187, 2026.

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.

Stier, P., et al.: The aerosol-climate model ECHAM5-HAM, Atmos. Chem. Phys., 5, 1125–1156, 2005.

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.