Project: **883**
Project title: **Modelling of Saharan mineral dust**
Project lead: **Bernd Heinold**
Report period: **1.1.2022 - 31.12.2022**

Progress Report

The central aim of this DKRZ project is to evaluate and continuously improve the representation of mineral dust in the aerosol-climate model ECHAM6.3-HAM2.3 (Tegen et al., 2019) and its successor ICON-A-HAM2.3 (Salzmann et al., 2021).

A substantial chunk of computing time was also used again for further testing the new aerosol-climate model ICON-A-HAM2.3. The model system consists of the recent atmospheric general circulation model ICON-A and the aerosol module HAM2.3, as inherited from ECHAM6.3-HAM2.3-MOZ1.0 and further adapted for ICON (Salzmann et al., 2021). During this allocation period, particular effort was put into the first release, which finally came on 8 February 2022. In addition, a lot of resources were spent porting ECHAM6.3-HAM2.3 and ICON-A-HAM2.3 to the new supercomputer Levante. The transition turned out to be more difficult than expected and a lot of computing time was used for trials. The performance tuning is not yet complete either. Nevertheless, a number of scientific goals were also achieved.

As one of the last years, 2020 was marked by some unprecedented aerosol events that were particularly interesting from an aerosol-climate research perspective. January to March saw the most severe forest fires in Australia's recent history (Black Summer), June brought the strongest Saharan dust event for 2 decades ("Godzilla" dust plume) and July to September also saw record fires in Siberia. Therefore, despite the actual focus on dust, part of the computational budget was again used to continue our ECHAM6.3-HAM2.3 simulations of the 2019/2020 extreme Australian wildfires. Biomass burning emissions were used from the Global Fire Assimilation System (GFAS) dataset. As the horizontal model resolution is too coarse to explicitly resolve pyroconvection, the Australian smoke emissions were explicitly prescribed to the lower stratosphere in different scenarios, based on unique lidar observations in Punta Arenas/Chile. Based on our simulations, the Australian fires caused a significant top-of-atmosphere instantaneous direct radiative forcing signal of up to +0.50 $W\,m^{-2}$, averaged for the Southern Hemisphere from January to March 2020 under all-sky conditions (Fig. 1). The signal is comparable to the radiative forcing induced by the total anthropogenic absorbing aerosol, which suggest that deep wildfire plumes inevitably need to be considered appropriately in climate projections for reasonable atmospheric energy budget estimates (Heinold et al., 2022).

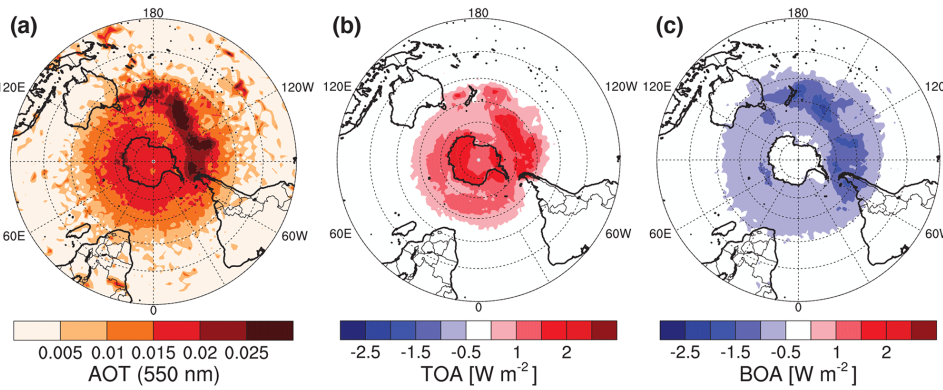

***Figure 1**: ECHAM6.3-HAM2.3 model results showing the aerosol optical thickness (AOT) and short-wave aerosol radiative forcing of the 2019–2020 Australian wildfire smoke for all-sky conditions at top (TOA) and bottom of the atmosphere (BOA).*

With regard to the representation of dust aerosol in the new model, the core objective of project 883, different freezing parameterisations for dust were tested.By default, heterogeneous freezing considers contact and immersion freezing of mineral dust following Lohmann and Hoose (2009), with modifications by Lohmann and Neubauer (2018). In addition, parameterisations from Niemand et al. (2012) and DeMott et al. (2015) were implemented and tested in first simulations. The horizontal grid resolution used in these model runs is R2B4 (approx. 160 km). The simulations were performed for 2 to 10 years between 2003 and 2012 in an AMIP setup with prescribed sea surface temperatures and sea-ice cover. As it turns out, the results are strongly sensitive to the freezing scheme of other aerosols, such as that for marine organic particles for example (Fig. 2). Further tests and an evaluation of the results are planned for the coming project period.

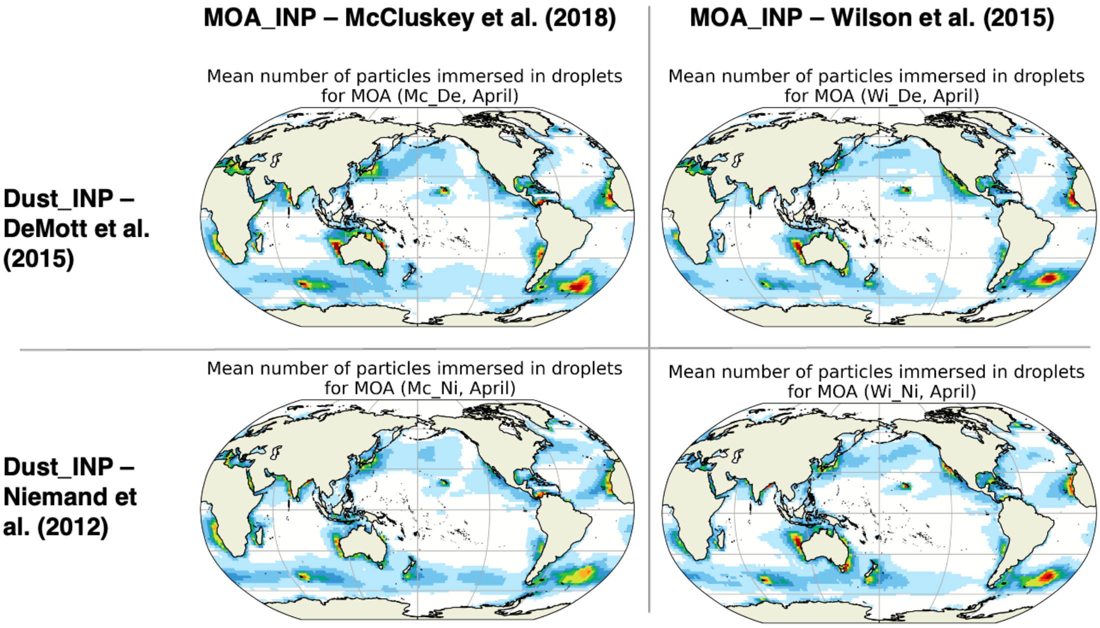

***Figure 2**: Number of particles immersed in droplets (potential ice-nucleating particles (INP)) as computed with ICON-A-HAM2.3 using different parameterisations for heterogenous freezing: Niemand et al. (2012) and DeMott et al. (2015) for mineral dust and McCluskey et al. (2018) and Wilson et al. (2015) for marine organic aerosol (MOA), respectively.*

Perspectives

Scientifically, model studies are planned for the June 2020 "Godzilla" dust plume, the largest Saharan dust plume in 20 years. And a novel dust emission scheme is still planned to be implemented in the HAM2.3 module, which is based on high-resolved satellite-derived albedo and was first tested in NOAA’s global aerosol model by B. Baker (ARL) and K. Schepanski (FU Berlin).

Utilisation and Publication

The modelling study on the Australian fires 2019-2020 by Heinold et al. was published in Atmos. Chem. Phys. All model developments and required input data are made available to the scientific community through the HAMMOZ website (https://redmine.hammoz.ethz.ch) and repository.

References

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