Project: **883**
Project title: **Modelling of Saharan mineral dust**
Project lead: **Bernd Heinold**
Report period: **1.1.2021 - 31.12.2021**

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., under rev.).

The year 2020, however, 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 (see Fig. 1). In addition, the Covid-19 pandemic and associated lockdown policies affected the aerosol pollution worldwide, whose influence on Tibetan dust we had already studied in the previous period (Fadnavis et al., 2021).

Part of the computing time allocation was therefore spent for ECHAM6.3-HAM2.3 simulations to investigate the dispersal of the Australian fire smoke and its radiative effects. Biomass burning emissions were prescribed by daily satellite-based estimates from the Global Fire Assimilation System (GFAS). As the horizontal model resolution is too coarse to explicitly resolve pyroconvection, the injection height over Australian was set to heights between 5 and 15 km and varied in terms of sensitivity studies. The model results were evaluated with ground and satellite remote sensing measurements. The sensitivity results showed how the fire injection heights affect the evolution of the smoke plume but also what role radiatively induced self-lifting plays. According to the model, the 2019-2020 Australian fires caused a significant top-of-atmosphere hemispheric direct radiative forcing of +0.88 W m^{-2}, averaged from January to March 2020. 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., to be subm.).

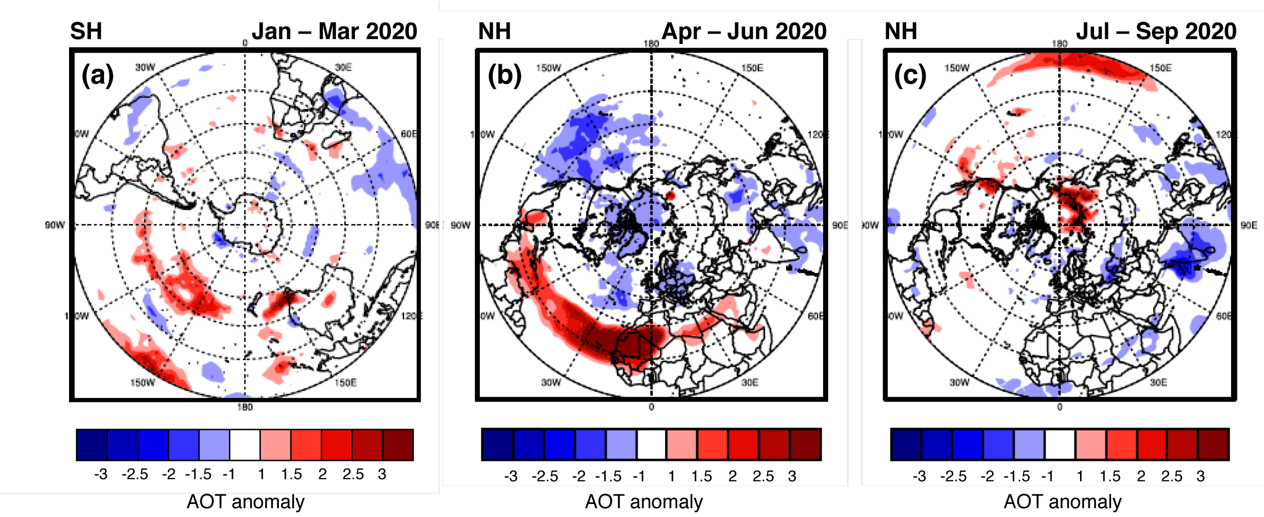

***Figure 1**: Anomalies in monthly mean AOT for 2020 compared to the long-term mean 2010-2019, normalized with standard deviation. The ECHAM6.3-HAM2.3 model results show positive AOT anomalies due to (a) Australia's 'Black Summer' wildfire smoke (Jan-Mar 2020), (b) 'Godzilla' Saharan dust plume (Apr-Jun 2020), and (c) Arctic smoke plume from record Siberian fires (Jul-Sep 2020).*

Like in the previous allocation period, a substantial chunk of computing time was also used 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).

Computing time was invested in particular in the preparation of a first pre-release in autumn this year.

As the main focus of this project, we are particularly interested in the representation of dust aerosol in the new model. Figure 2 shows as an example the mean global dust load from a 10-year simulation with ICON-A-HAM2.3 compared to corresponding model results from ECHAM6.3-HAM2.3. The horizontal grid resolution used in these simulations was R2B4 (approx. 160 km) for ICON-A and T63 (approx. 200 km) for ECHAM6.3. The simulations were performed for the years 2003 to 2012 in an AMIP setup with prescribed sea surface temperatures and sea-ice cover. Other than ECHAM6.3-HAM2.3, ICON-A-HAM2.3 again avoids regional differentiation of the scaling factor for the dust emission threshold and instead uses a constant parameter. The new model generally produces less dust, but the Bodélé region as the main Saharan dust source is more pronounced and stronger dust emissions are modelled in Australia, which is considered positive (Fig. 2).

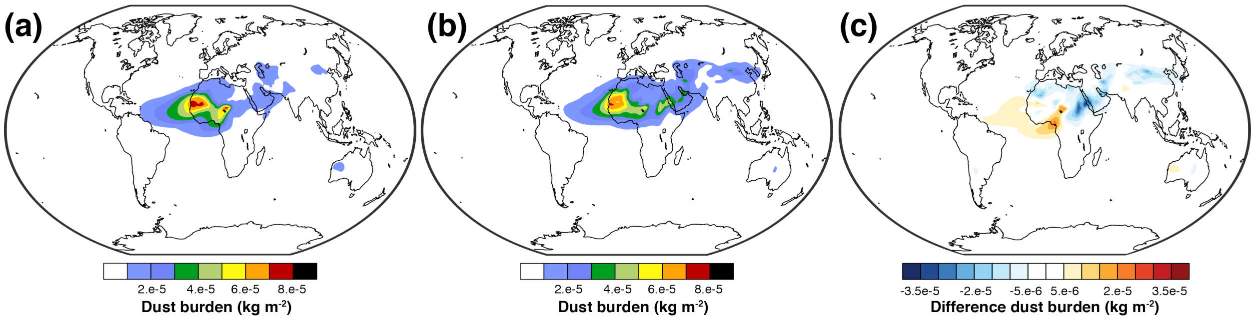

Figure 2*: Mineral dust burden averaged over the years 2003 to 2012 as computed by the models (a) ICON-A-HAM2.3 and (b) ECHAM6.3-HAM2.3 and (c) difference ICON-A-HAM2.3 minus ECHAM6.3-HAM2.3 (M. Salzmann).*

Perspectives

Scientifically, new dust 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 aerosol module HAM2.3, 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 (TROPOS, now at FU Berlin).

Utilisation and Publication

The modelling study on the Australian fires 2019-2020 will soon be submitted by Heinold et al. to the journal 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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