Project: **883**
Project title: **Modelling of Saharan mineral dust**
Project lead: **Bernd Heinold**
Report period: **1.1.2020 - 31.12.2020**

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. In recent allocation periods, the focus has been mainly on the so-called Dust Belt region, which spans from North Africa to Central Asia.
The year 2020, however, was marked by a couple of unprecedented events, that were particularly interesting from an aerosol and climate research perspective, most notably the Covid-19 pandemic and associated lockdown policies. Therefore, part of the granted computing resources was used to contribute to a modelling study on the impact of Covid-19 lockdown measures on the Asian summer monsoon led by Suvarna Fadnavis (Indian Institute of Tropical Meteorology, Pune) and colleagues. The simulations were performed with the latest model version ECHAM6.3-HAM2.3 at resolution T63L31. Bottom-up estimates of anthropogenic emissions based on national mobility data from Google and Apple were used to reproduce the observed decline in air pollution. Observations of aerosol optical depth (AOD) showed that the lockdown measures caused a substantial drop in Asian aerosol loadings, with approx. 40 % reductions over the Indo-Gangetic plain in the 2020 pre-monsoon season compared to the 2000-to-2019 average. As a result, an increase in net surface solar radiation of 4 Wm^{-2} was modelled over parts of South Asia due to the lower direct aerosol radiative effect. The model simulations also reveal a complex feedback upon the atmospheric circulations. The gain in radiation resulted in a strengthening of the Asian Summer Monsoon (ASM). Simultaneously, a warm core over the Tibetan plateau, generated by accumulated dust aerosols during the pre-monsoon season in 2020, reinforced the intensification of the Hadley circulation. The associated cross-equatorial moisture influx over the Indian landmass led to a 5–15% increase in precipitation over India. The ECHAM-HAM model study suggests that the reduced anthropogenic emissions caused by the unprecedented Covid-19 restrictions have had a beneficial effect on the water cycle in South Asia, which has been facing water shortages and frequent draught conditions in recent decades (Fadnavis et al., subm.).

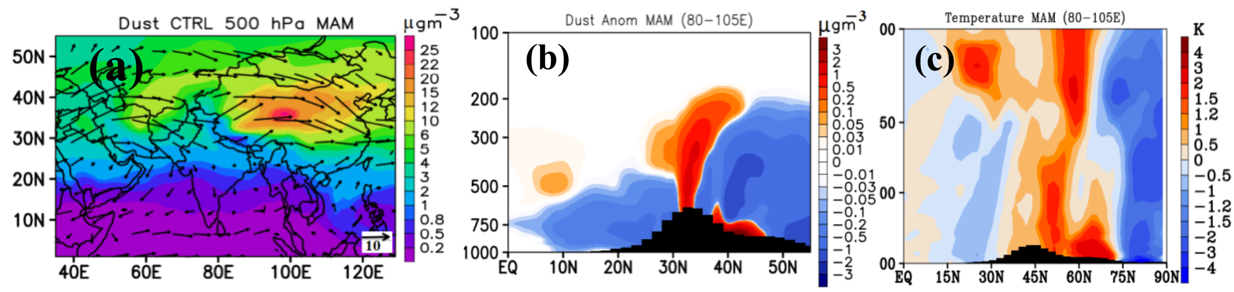

***Figure 1**: Results of the Covid-19 study using ECHAM6.3-HAM2.3: (a) distribution of dust and 500-hPa winds (MAM 2020), (b) cross section of anomalies in dust (Covid-19 – control, averaged over 80–105ºE), (c) anomalies of seasonal mean temperature (pre-monsoon) averaged over the Tibetan Plateau region (80–105 ºE) (S. Fadnavis).*

In addition, computing time was used for initial simulations with the new aerosol-climate model ICON-A-HAM2.3. The model system consists of the new atmospheric general circulation model ICON-A (Giorgetta et al., 2018) and the aerosol module HAM2.3 as known from the coupling with ECHAM (Salzmann et al., in prep.). According to the focus of this computing project, we were particularly interested in the performance of the new system in dust modelling. As an example, Figure 2 shows the global mean dust burden 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, respectively. ICON-A used a vertical hybrid sigma height coordinate with 47 levels, while ECHAM6.3 used a vertical hybrid sigma pressure coordinate with 47 levels with a slightly higher resolution in the upper troposphere than ICON-A. The simulations were performed for the years 2003 to 2012 in an AMIP setup with prescribed sea surface temperatures and sea-ice cover as in the ECHAM6.3-HAM2.3 reference setup (Tegen et al., 2019). As in the previous model, dust emissions are also computed in ICON-A-HAM2.3 based on wind speed, soil wetness and snow cover. However, the new model again avoids a regional differentiation of the scaling factor for the dust emission threshold and uses a constant parameter instead. ICON-A-HAM2.3 shows in general a smaller dust production, but the Bodélé depression as a major source of dust is more pronounced and also in Australia stronger dust emissions are modelled, which altogether is positive (Fig. 2). However, a thorough model evaluation will of course require detailed comparisons with dust observations, which is planned for the next allocation period.

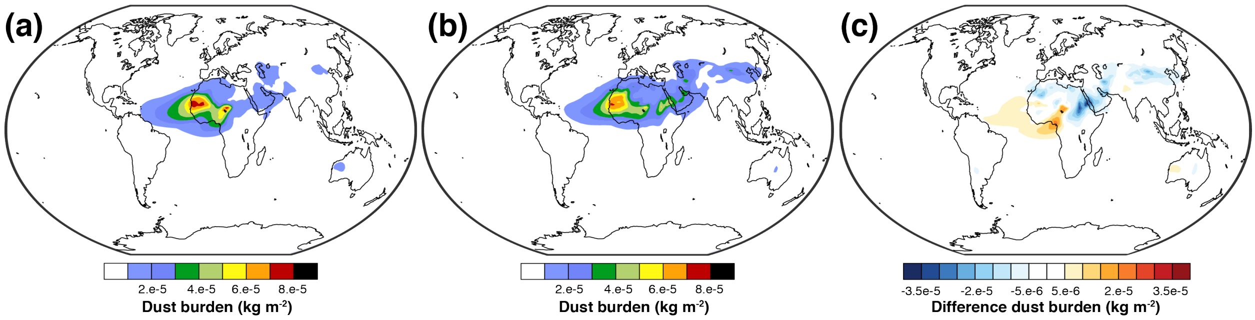

***Figure 2**: Maps of mineral dust burden averaged over the years 2003 to 2012 as computed by the models (a) ICON-A-HAM2.3 and (b) ECHAM6.3-HAM2.3 and (c) difference ICON-A-HAM2.3 minus ECHAM6.3-HAM2.3 (M. Salzmann).*

Perspectives

A novel approach for dust emission computations will be implemented in the aerosol module HAM2.3, which is based on high-resolved satellite albedo products and has currently being tested in NOAA’s global aerosol model by B. Baker (ARL) and K. Schepanski (TROPOS). In addition, a further detailed evaluation of the dust results of ICON-A-HAM2.3 with observations is planned.

Utilisation and Publication

The Covid-19 modelling study was submitted for publication in the journal Environmental Science Letters by Fadnavis et al. 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

Fadnavis, S., Sabin, T. P., Rap, A., Müller, R., Kubin, A. and Heinold, B., The impact of COVID-19 lockdown measures on the Asian summer monsoon, Environ. Res. Lett., submitted.

Heinold, B. and Tegen, I.: Modelling mineral dust in the Central Asian region, Central Asian DUst Conference (CADUC 2019), Dushanbe, Tajikistan, Ed. Altausen, D., Abdullaev, S. and Hofer, J., E3S Web of Conferences, Volume 99, 02012, doi:10.1051/e3sconf/20199902012.

Salzmann et al., The global atmosphere-aerosol model ICON-A-HAM2.3, J. Adv. Model. Earth Syst., in preparation.

Tegen, I., Neubauer, D., Ferrachat, S., Siegenthaler-Le Drian, C., Bey, I., and co-authors: The global aerosol–climate model ECHAM6.3–HAM2.3 – Part 1: Aerosol evaluation, Geosci. Model Dev., 12, 1643–1677, https://doi.org/10.5194/gmd-12-1643-2019, 2019.