Project: **1004**

Project title: **Development and evaluation of aerosol processes in ECHAM-HAMMOZ**

Project lead: **Bernd Heinold, Ina Tegen**

Report period: **2018-07-01 to 2019-06-30**

The aim of his project is the on-going evaluation and coordination of further developments of the aerosol model HAM (Versions 2.2, 2.3) in close collaboration with scientists from the HAMMOZ consortium. The well-established global aerosol-chemistry-climate model ECHAM6-HAMMOZ is jointly developed by partners from several European universities and research institutes. The model code is hosted at the ETH Zurich where it is made accessible to the research community; partners include scientists at the Universities of Oxford, and Helsinki, as well as at the German research institutes MPI Hamburg, GEOMAR and TROPOS. ECHAM-HAMMOZ simulates the life-cyles of climate-relevant aerosol species including microphysical transformation processes, and their climate impact. The model system includes the global atmospheric climate model ECHAM (current version 6.3), the aerosol-microphysics model HAM (current version 2.3), and the atmospheric chemistry model MOZART. The role of TROPOS in this project is to bring together the different aspects of the model development and to test the subsequent modifications in the aerosol distribution resulting from the changes of the aerosol parameterisation

During the period 07/2018 to 04/2019, continuous tests tests and bug-fixes of the model version ECHAM6.3-HAM2.3-MOZ released in February 2017 were carried out. Several manuscripts describing the changes and performance of the new and considerably updated model version model were submitted and partly already by the international HAMMOZ consortium. These include the following publications acknowledging DKRZ support:

Publications using results from this project 1004, within the reporting period

TROPOS lead: Tegen et al., 2019, (GMD, accepted), Tegen and Heinold, 2018, (Atmosphere)

Publications with TROPOS support: Huang et al, 2018 (ACP), Kokkola et al., 2018 (GMD), Neubauer et al (GMDD, submitted)

In addition to model tests, a major part of the resources in allocation period was used for simulations used in the model aerosol evaluation publication that is accepted for publication in GMD (Tegen et al., 2018). There the overall performance and individual aerosol species for the standard model setup were compared with a wide range of available observations (optical thickness, angstrom exponent, in-situ surface and aircraft observations, size distribution). These comparisons were done for three setups for 10-year simulations for the years 2003 to 2012 (ACCMIP emissions, nudged and climatological, GFAS emissions nudged), as well as four simulations testing different seas salt emission schemes. The model still underestimated the carbonaceous aerosol concentration in near surface stations as well as the coarse mode aerosol burden, but showed overall good agreement with Aeronet sunphotometer optical thickness data (as example see Figure 1).

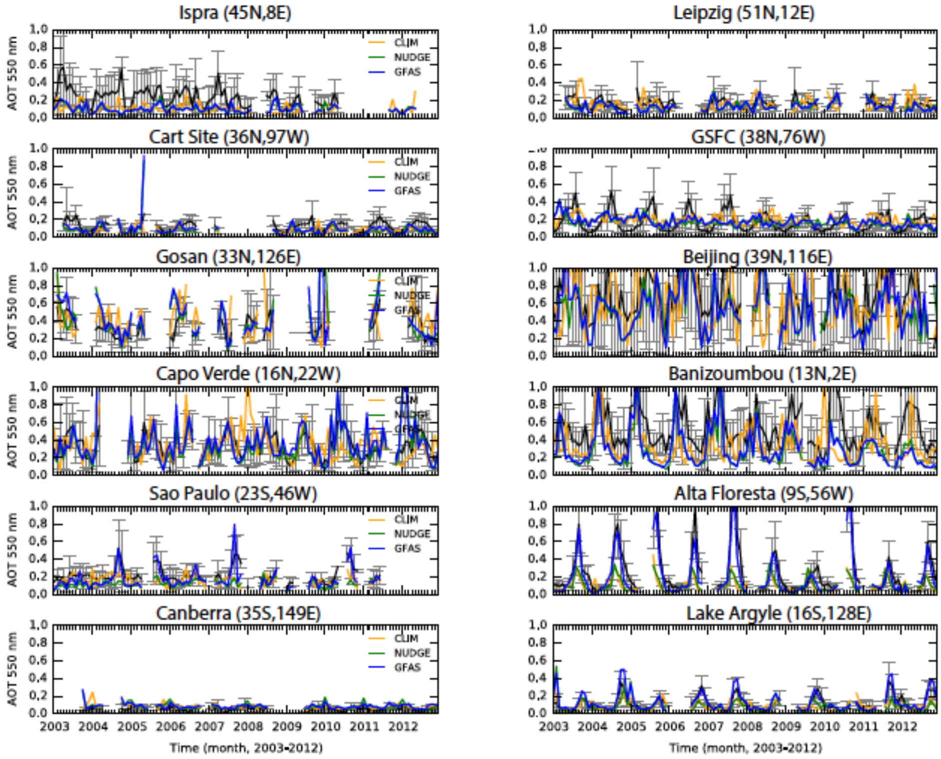

Figure 1: Time series of observed (black line) and simulated AOT (colored lines) from Jan 2003 to Dec 2012 at selected AERONET stations. Simulated monthly mean were constructed from the daily mean outputs sampled on the same days of the observations and collocated to the observation position. Error bars show the variabilities of the measurements. From Tegen et al. (2019).

The magnitudes and temporal variations in AOT for the simulations are mostly well matched with the observations. Seasonal and interannual variabilities are generally well reproduced in the model. The better match of the results from the nudged simulations in stations largely impacted by long-range transported aerosol such as Capo Verde is evident. While at most stations the magnitude of the AOTs are well matched between model and observations, there are some exceptions: E.g. at the Ispra site in northern Italy all model results underestimate the measurements by 5 about a factor 2, and at the station GSFC in Maryland, USA the observed seasonal cycle is not reproduced. The underestimation of AOT in the model at the location of Ispra may be explained by a misrepresentation of the topography at the location near the foothills of the Alps and thus the atmospheric flows. Otherwise, even in highly polluted urban locations such as Beijing the model results and observations are well matched in terms of magnitude and temporal variations at monthly and interannual timescales. The same is the case for locations with very low AOT (Canberra).

Another part of the resources was used to investigate the so-called semi-direct effect of absorbing aerosol (black carbon (BC) and dust). As coarse mode aerosol from dust emissions may be underestimated in the model, the dust effect due to absorption may still be misrepresented (although there is agreement in model single scattering albedo with inversions from AERONET sunphotometer data, Figure 2)

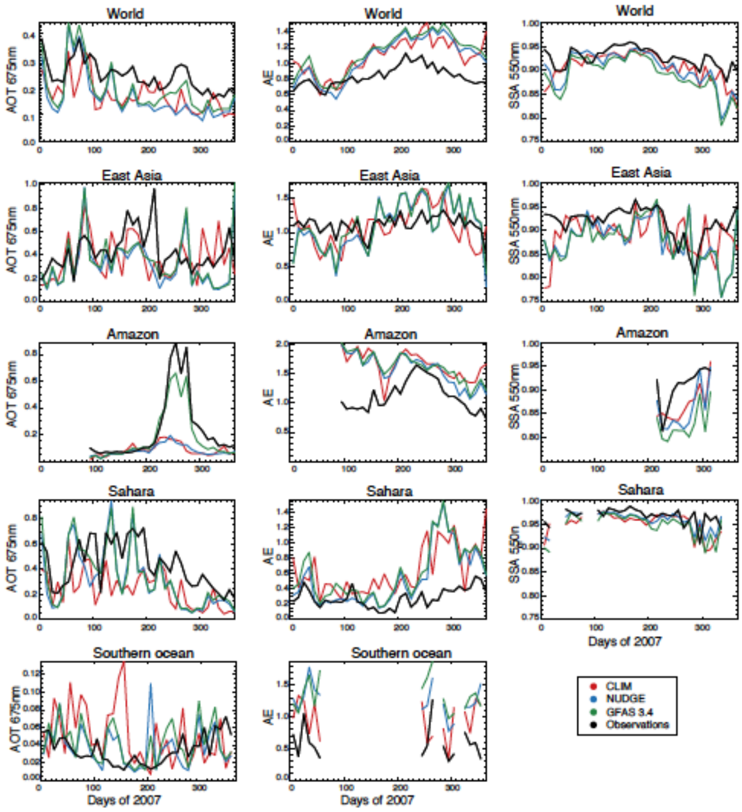

Figure 2: Annual cycle of AOT (left panels), AE (middle panels) and SSA (right panels) from AERONET retrievals for global averages and summarized for several regions (top-to-bottom panels: World, East Asia, Amazon, Sahara, Southern oceans) for the year 2007. From Tegen et al. (2019).

Table 1: Results of the global annual average top-of-atmposphere direct radiative effect (DRE), instantaneous direct radiative effect (IDR) and semi-direct radiative effect computed from pairs of model simulation Additionally, results for solar (SW) and thermal (LW) parts of the spectrum are provided, as well as total cloud cover changes. (see Tegen and Heinold, 2018)

Simulation	**DRE** Wm^{-2}	**IDR** Wm^{-2}	**SDE (Net)** Wm^{-2}	**SDE (SW)** Wm^{-2}	**SDE (LW)** Wm^{-2}	**Cloud cover** %
All aerosol	−1.13(0.45)	−1.22(0.05)	0.08 (0.45)	0.08 (0.57)	0.01 (0.47)	−0.01 (0.40)
BC forcing, including dust	0.51 (0.47)	0.42(0.06)	0.09 (0.47)	0.19 (0.58)	−0.10(0.49)	−0.25 (0.41)
BC forcing, excluding dust	0.24 (0.46)	0.27(0.01)	−0.03(0.46)	−0.03(0.57)	0.00 (0.50)	−0.08 (0.41)

Numbers in brackets are standard deviations based on results for individual model years.

The model results indicate that while the overall effect of black carbon on cloud cover by changes in heating rates is small and uncertain (Table 1), the presence of under- or overlying mineral dust may enhance or reduce the effects of black carbon, respectively. Enhancement of BC positive forcing occurs in the Sahel and tropical Atlantic regions, while reduction of the BC effect occurs in mid-latitudes when high dust layers overlay BC aerosol in the boundary layer. This modifies the overall black carbon effects as short-lived climate forcing in the climate system.

Publications:

Huang, W.T.K., L. Ickes, I. Tegen, M. Rinaldi, D. Cerbunis, and U. Lohmann, 2018. Global relevance of marine organic aerosols as ice nucleating particles, Atmos. Chem. Phys., 18, 11423-11445, https://doi.org/10.5194/acp-18-11423-2018

Kokkola, H., Kühn, T., Laakso, A., Bergman, T., Lehtinen, K. E. J., Mielonen, T., Arola, A., Stadtler, S., Korhonen, H., Ferrachat, S., Lohmann, U., Neubauer, D., Tegen, I., Siegenthaler-Le Drian, C., Schultz, M. G., Bey, I., Stier, P., Daskalakis, N., Heald, C. L., and Romakkaniemi, S., 2018. SALSA2.0: The sectional aerosol module of the aerosol-chemistry-climate model ECHAM6.3.0-HAM2.3-MOZ1.0, Geosci. Model Dev. , 11, 3833-3863, https://doi.org/10.5194/gmd-11-3833-2018.

Neubauer, D., S. Ferrachat, C. Siegenthaler-Le Drian, P. Stier, D. G. Partridge, I. Tegen, I. Bey, T. Stanelle, H. Kokkola, and U. Lohmann, 2018. The aerosol-climate model ECHAM6.3-HAM2.3: Part 2: Cloud evaluation, submitted to Geophys. Mod.. Discuss

Tegen, I. and B. Heinold, 2018. Large-scale modeling of absorbing aerosols and their semi-direct effects, Atmosphere, 9(10), 380.

Tegen, I., D. Neubauer, S. Ferrachat, C. Siegenthaler-Le Drian, I. Bey, N. Schutgens, P. Stier, D. Watson-Parris, T. Stanelle, H. Schmidt, S. Rast, H. Kokkola, M. Schultz, S. Schroeder, N. Daskalakis, S. Barthel, B. Heinold, and U. Lohmann, 2019. The aerosol-climate model ECHAM6.3-HAM2.3: Part 1: Aerosol evaluation, accepted for Geosci. Model Dev. gmd-2018-235.