Project: **1004**

Project title: **Development and evaluation of aerosol processes in the community aerosol chemistry model HAMMOZ**

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

Report period: **2022-07-01 to 2023-06-30**

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 Leipzig, at the Finish Meteorological Institute (FMI), as well as at the German research institutes MPI Hamburg, TROPOS and GEOMAR. It simulates the lifecycles of the climate-relevant aerosol species including microphysical transformation processes, and their impact on clouds, radiation and climate. The model system includes the global atmospheric climate model ECHAM, the aerosol-microphysics model HAM, 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.

The new aerosol-climate model ICON-HAM (Salzmann et al., 2022) was released 2021. Here, the HAM (version 2.3) aerosol model is coupled to the climate model ICON-A (icon-aes-1.3.00). TROPOS has the responsibility to prepare and maintain the input data for the new model system. Thus, to enable users to fully explore the new model, in addition to a comprehensive set of input data tailor-made data for, e.g. the development of a fire-related dust emission parameterisation based on fire radiative power were prepared in the allocation period.

Both models, ECHAM6.3-HAM2.3-MOZ model (released 2017) and ICON-HAM were ported to the new HPC system Levante.

Computing time granted for the report period was used for

a) <u>Test simulations on the effects of a bug in the nudging code</u>
We were made aware of a bug in the nudging code of ECHAM6-HAMMOZ in February 2022. There is a problem with the nudging of log surface pressure, which is read only at the first time step of a month and then remains unchanged until a new input file is opened at the beginning of the next month. Since recent production runs conducted by TROPOS researchers were affected by this bug, some test simulations were set up in order to investigate the effect on the surface pressure field, the near-surface winds and the wind driven aerosol emissions of, e.g., mineral dust and sea salt. In the meantime it became clear, that the buggy reading of nudging input data depends on the nudging data set, e.g. ERA-Interim data (Dee et al., 2011) or ERA5 data (Hersbach et al., 2020), and also on the preparation date of the nudging data files, i.e. younger ERA-Interim files and all ERA5 files are causing problems while older files do not.
The test case was run in T63 horizontal resolution and with 47 levels in the vertical. ERA5 data were used for nudging. At the lower boundary sea surface temperatures and sea ice conditions were prescribed. Two different executables were compiled, one with the bug

and the other with a corrected code. A third simulation was carried out with the buggy code but with surface pressure nudging switched off. The year 2020 was chosen as it had a particularly interesting Saharan dust outbreak, nicknamed ‘Godzilla’ in June. The results for globally integrated emissions of dust and sea salt show a reduction of the emissions when the bug is present in the code. Closer analyses for certain regions, e.g. North Africa as the main dust emission region and the Southern Ocean as a source region for sea salt aerosol reveal a similar picture, i.e., the emissions are higher when the bug is removed and pressure nudging data are read continuously instead of once per month. However, the case study of the Godzilla dust storm in June 2020 showed that this general tendency might not hold for individual events. The dust storm was stronger in the simulation with the bug, most probably due to high wind speeds in the beginning of June which then erroneously persisted throughout the month. The near-surface winds over northern Africa are affected adversely in that the turn of the meridional winds related to the African Summer Monsoon is delayed by one month.

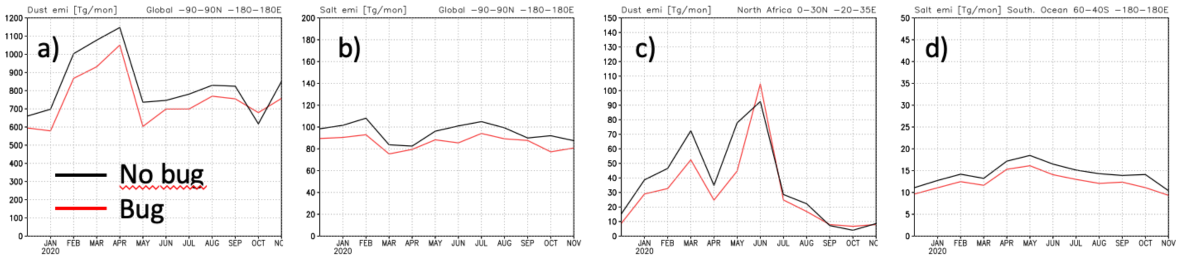

***Figure 1**:* Comparison of simulated emissions of wind-driven aerosol in ECHAM6.3-HAM2.3 with a bug in the nudging code (red) and with the corrected code (black). Global emissions of a) dust and b) sea salt, and regional emissions of c) North African dust and d) sea salt over the Southern Ocean from Dec 2019 to Nov 2020. Units are Teragram (Tg) per month.

b) <u>Dust simulations with ICON-HAM</u>

In order to get to know better the behaviour of the new aerosol-climate model ICON-HAM with regard to dust emissions simulations were set up with different settings for the dust code. In the well-established model ECHAM6-HAM2.3 it was necessary to re-tune dust emissions depending on the computation of the roughness length (including orography or vegetation in terms of leaf area index) and even depending on the region. To find out, if a similar tuning is necessary in ICON-HAM. Two simulations were performed spanning one year each. One uses the Stier et al. (2005) scheme and the other in addition to the Stier et al. scheme a dust emission mask for the Sahara desert based on Meteosat Second Generation (MSG) observations (Heinold et al., 2016). The focus of the analyses was on North Africa and on dust emission rates and aerosol optical thickness (AOD).

The global annual dust emission is 813 and 814 Tg (Teragram) in both simulations which is in reasonable agreement with the results of Salzmann et al. (2022), who found values between 820 and 940 Tg depending on the experimental setup. From a global intercomparison project (AeroCom Phase I) the range of model results reaches from 500 to about 4000 Tg dust emission per year (Huneeus et al., 2011). More than half of the global emission originates from North Africa, where we found 450 and 470 Tg in the simulation without and with the MSG mask, respectively.

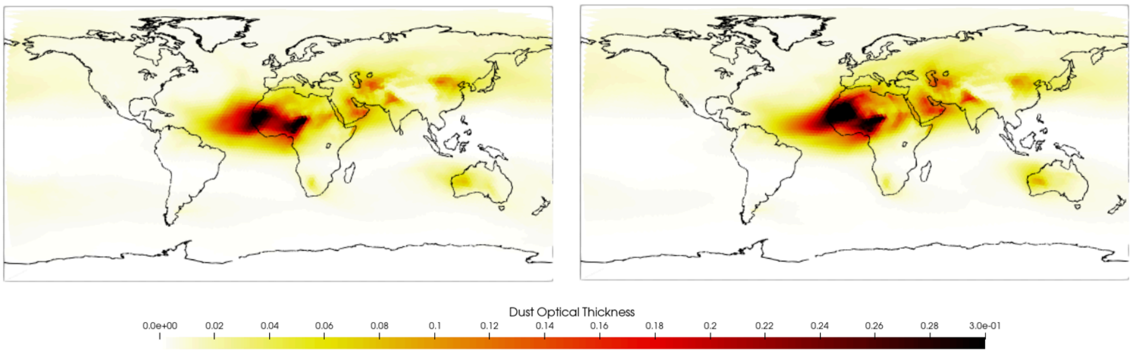

Figure 2*:* ICON-HAM dust aerosol optical thickness (AOT) in August 2010 as simulated with different dust source representations. Left: Standard as in ECHAM6-HAM as described in Tegen et al. (2019), right: with additional MSG source mask as in Heinold et al. (2016).

c) Ensemble simulations of the Australian wildfire season 2019/2020
The simulations of the severe Australian wildfires during the 2019/20 fire season (Heinold et al., 2022), which were intended to reproduce the actual situation, were complemented by ensemble simulations without nudging. The initial ensembles consisted of six members each, spanning the six months from October 2019 to March 2020, and served to further investigate the circulation response to the Australian wildfires. It was found that the ensemble size of six is not sufficient to get statistically robust signals in the circulation variables. As a consequence, the ensemble size was increased to 36 members and, moreover, a scaling of the fire strength from 0 (no fires), 1 (fires as in the original GFAS emission data), 2, 3 and 5 (5 times as emissive fires as in the original GFAS data set), was applied. This approach resulted in 180 simulations, which were prepared (automated script generation, etc.) in project bb1004 but computed in project bb1262. A publication is currently under review for ACP (Senf et al., 2023).

d) Porting the models to the Levante HPC system
As the new HPC system Levante became available in 2022 porting, performance tuning and extensive testing of the two models ECHAM6-HAM2.3-MOZ1.0 and ICON-HAM became necessary. Numerous test simulations were run, most of them covering six month.

Publications:

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