Project: **1005**

Project title: **Model-based quantification of aerosol and cloud processes and their effects in the Arctic**

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Report period: **2017-07-01 – 2018-06-30**

Progress Report

The impact of aerosol on Arctic climate and the observed rapid climate change is explored by global and Arctic-focused simulations within the DFG Transregio TR 172 'Arctic Amplification $(AC)^3$'. The aim of this project is to perform and evaluate the simulations with the global aerosol-climate model ECHAM6-HAM2 and the regional transport model COSMO-MUSCAT that are used to investigate the sources and transport pathways of aerosol particles as well as their impact on radiation, clouds, and atmospheric dynamics in the Arctic region. The model evaluation particularly focuses on the representation of the layering and seasonal cycle of aerosol, which are the key challenges. This includes considering the impact of ageing and mixing on particle properties.

During the period 07/2017 to 06/2018, computing time has been spent to continue investigating the emission-related uncertainties in the distribution and effects of aerosol in global ECHAM6-HAM2 simulations. The evaluation study makes use of the model version ECHAM6.3-HAM2.3 and comprises different combinations of state-of-the-art emission datasets for anthropogenic air pollutants and biomass burning. In addition to the widely-used ACCMIP inventory, the anthropogenic emission database ECLIPSE v5a is tested, which covers more recent years and includes gas flaring as well as different ship emission scenarios. Moreover, a new high-resolution emission inventory for black carbon (BC) over Russia (BCRUS; Huang et al., 2015) is used. Actual daily fire emissions are taken from GFAS. The different ECHAM6.3-HAM2.3 runs are performed in nudged mode at T63 horizontal resolution with 47 vertical levels for the years 2008–2017. The model results are compared among each other and evaluated against ground-based and airborne BC measurements, observations of aerosol optical depth from AERONET sun photometer stations, and satellite remote sensing.

The analysis mainly focuses on BC aerosol, which tends to warm the climate. BC is typically transported from urban and industrial sources in Europe and SE-Asia, but also local shipping and oil/gas extraction and widespread, mainly natural boreal forest fires can contribute significantly. The typical transport patterns are well represented in the simulations. Depending on the emission data used, the annual mean burden of BC varies considerably by more than 30 % in the central Arctic and up to 70 % in Siberia (Figure 1).

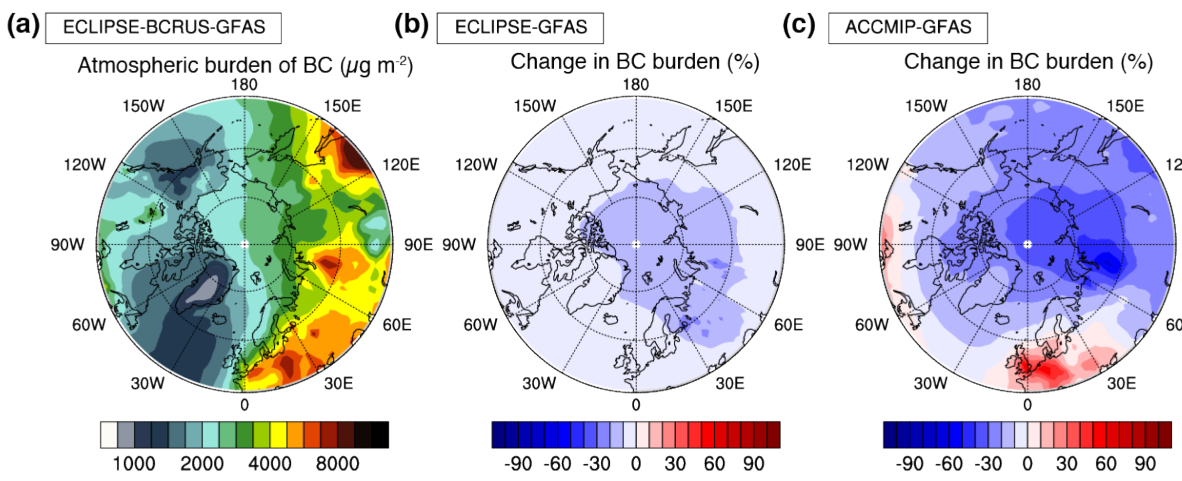

***Figure 1**: (a) Annual mean burden of BC for the years 2008-2012 as computed by ECHAM6.3-HAM2.3 using the ECLIPSE-BCRUS-GFAS emissions. Difference in BC burden between the run using ECLIPSE-BCRUS-GFAS and runs using the (b) ECLIPSE-GFAS and (c) ACCMIP-GFAS emission data.*

Comparisons to station measurements of BC in the Arctic show that the model is able to reproduce both the order of magnitude and the annual cycle (Figure 2). However, when comparing to aircraft observations, in particular, a strong overestimation of modelled BC load is found at mid-troposphere levels. The results of ECHAM6.3-HAM2.3 have considerably improved compared to a previous model version in earlier model intercomparison studies, in which the BC load was dramatically underestimated at near-surface level and more strongly overestimated aloft (cf. Eckhardt et al., 2015 and Schwarz et al., 2017, respectively).

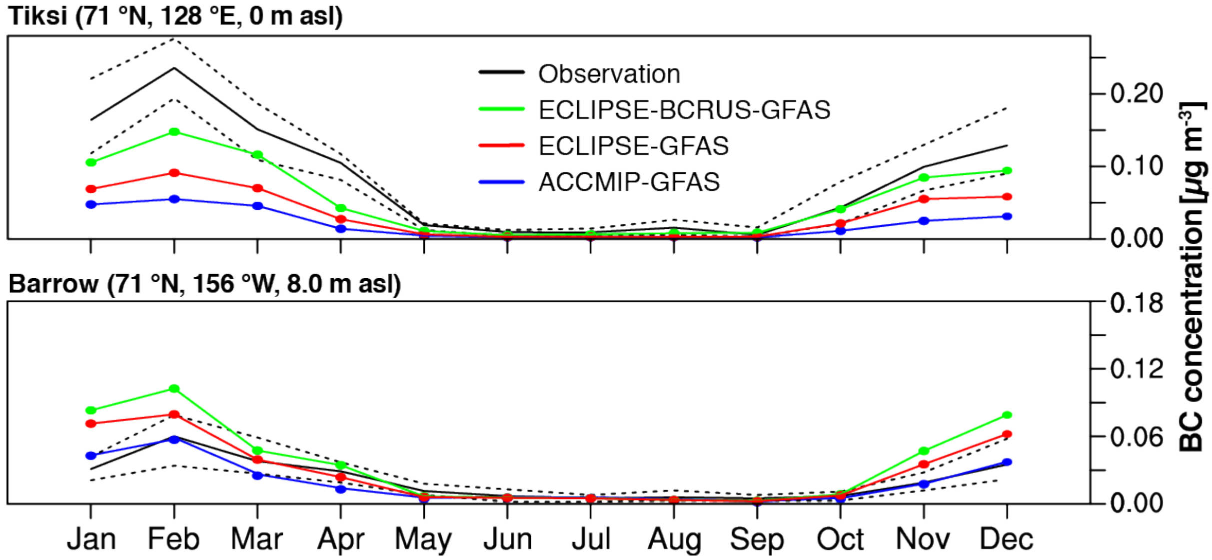

***Figure 2**: Seasonal cycle of modelled median BC mass concentration compared to observations from the Arctic stations Tiksi and Barrow, averaged over the years 2012–2014 and 2012–2015, respectively. The black solid line shows the observational median and the black dashed lines are the upper and lower quartile. Colored lines indicate the results of the different ECHAM6.3-HAM2.3 runs using different emission inventories.*

Perspectives

The good agreement between model results and surface observations near source regions as well as the overestimation at mid-tropospheric levels in the Arctic suggests an overestimation of the aerosol lifetime in ECHAM6-HAM2. In future runs, this issue will be addressed by a more efficient particle ageing and/or attributing BC emissions to coarser particle sizes. After thorough evaluation, the model results will be used to obtain a state-of-the-art estimate of the aerosol budget and the effective radiative forcing by anthropogenic aerosols in the Arctic region.

Utilisation and Publication

This work contributes to the evaluation of the latest model version ECHAM6.3-HAM2.3(-MOZ1.0), for which several manuscripts are currently in preparation by the HAMMOZ consortium. The results have already been presented at several science conferences and workshops. A paper publication is currently prepared and will be submitted to ACPD in summer 2018.

References

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Huang, K., J. S. Fu, V. Y. Prikhodko, J. M. Storey, A. Romanov, et al. (2015), Russian anthropogenic black carbon: Emission reconstruction and Arctic black carbon simulation, Journal of Geophys. Res. Atmos., 120(21), doi: 10.1002/2015JD023358.

Schwarz, J. P., B. Weinzierl, B. H. Samset, M. Dollner, K. Heimerl, et al. (2017), Aircraft measurements of black carbon vertical profiles show upper tropospheric variability and stability, Geophys. Res. Lett., 44, doi:10.1002/2016GL071241.