Project: **1005**

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

Project lead: **Bernd Heinold**

Report period: **01.07.2016 – 30.06.2017**

Progress Report

Within the framework of the DFG Transregional Collaborative Research Centre TR 172 '*Arctic Amplification (AC3)'*, the role of aerosol particles in the Arctic climate is explored by global and Arctic-focused simulations using the aerosol-climate model ECHAM6-HAM2 and the regional aerosol transport model COSMO-MUSCAT. It is the aim of this project to perform and evaluate the model simulations that provide the basis to study sources and transport pathways of aerosol to the Arctic region, as well as to quantify the aerosol impact on radiation and clouds. The evaluation considers the impact of ageing and mixing of aerosol particles and the snow/ice-albedo forcing, with a particular focus on black carbon (BC).

The computing time granted for the period 07/2016 to 06/2107 was spent on testing different state-of-the-art emission inventories in aerosol transport simulations with the new ECHAM6.3-HAM2.3 model (available since 02/2017; pre-release version before). The sensitivity and evaluation study aimed to address the questions of: (i) How well are sources and transport of aerosol to the Arctic temporally and spatially reproduced? and (ii) What are emission-related uncertainties in direct aerosol radiative forcing? ECHAM6.3-HAM2.3 was run in nudged mode at T63 horizontal resolution with 47 vertical levels for the 10-year period 2006–2015. The model results were compared among each other and evaluated against ground-based and airborne BC measurements, observations of aerosol optical depth from AERONET sun photometer stations, and space-borne CALIPSO lidar observations.

The key focus of the analysis was on BC aerosol. BC is typically transported from urban and industrial sources in Europe and South-East Asia, but can also originate from widespread (mainly natural) boreal forest fires and local ship tracks. Our results agree with the findings of previous aerosol transport studies, suggesting that typical transport patterns are well captured by the model (Figure 1).

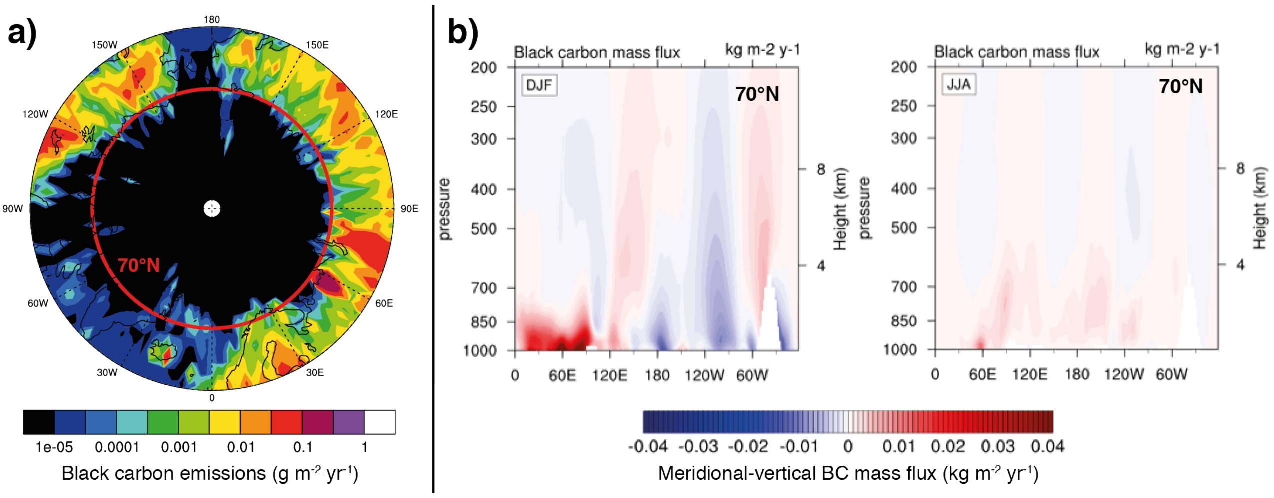

Figure 1*: (a) Yearly emission fluxes of black carbon as prescribed from the ECLIPSE inventory, including emissions from gas flaring and ship traffic, and GFAS land fire data. (b) Meridional-vertical mass flux of black carbon at latitude 70°N for the winter months December to February (DJF) and summer months June to August (JJA) as computed by ECHAM6.3-HAM2.3 with ECLIPSE/GFAS emissions and averaged over the period 2005 – 2016. Red and blue colours indicate northward and southward BC transport, respectively.*

Comparisons to station measurements of monthly mean surface BC concentrations in the Arctic reveal that the model is able to reproduce both the order of magnitude and in general the annual cycle. When comparing to aircraft observations, in particular, a strong overestimation of modelled BC load is found at high altitudes (Figure 2). 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 (not shown; cf. Eckhardt et al., 2015 and Schwarz et al., 2017, respectively).

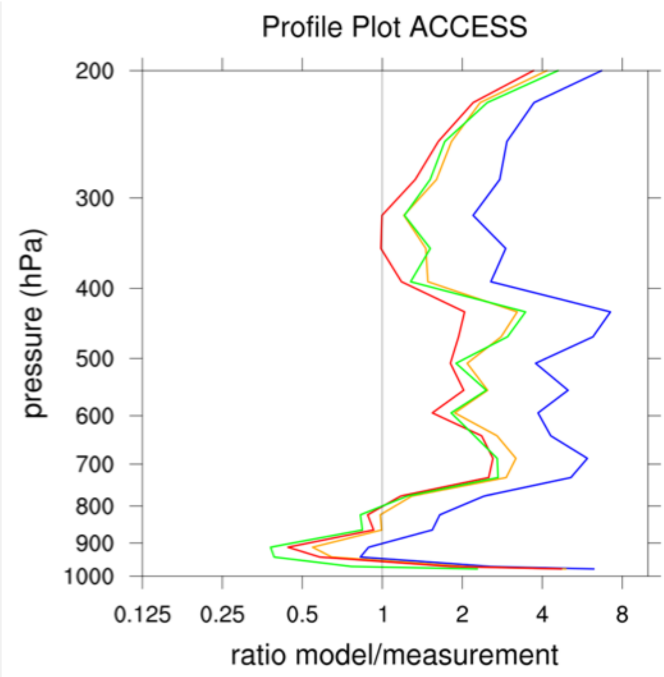

***Figure 2**: Model-measurement ratios of mass mixing ratios of black carbon (BC) for the ACCESS aircraft campaign over Norway and Svalbard in July 2012 (Schwarz et al., 2017). The line colours indicate model results from different ECHAM6.3-HAM2.3 runs using different emission datasets (green: ECLIPSE/GFAS; red: ACCMIP; orange: ACCMIP/GFAS; blue: ACCMIP/GFAS increased by factor 3.4).*

Perspectives

The range in the model results so far suggests large differences in the aerosol effect on radiation and clouds in the Arctic for the different emission datasets. Further comparison to observations is needed to select a suitable setup. 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 will contribute to the evaluation of the freshly released model version ECHAM6.3-HAM2.3(-MOZ1.0), for which several manuscripts are currently in preparation by the international HAMMOZ consortium. First results were presented in talks at the first $(AC)^3$ science conference in Bremen, Germany in March 2017 and at a session at the EGU 2017 general assembly in Vienna, Austria in April 2017. A first paper publication is envisaged in the second half of 2017.

References

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Schwarz, J. P., B. Weinzierl, B. H. Samset, M. Dollner, K. Heimerl, M. Z. Markovic, A. E. Perring, and L. Ziemba (2017), Aircraft measurements of black carbon vertical profiles show upper tropospheric variability and stability, Geophys. Res. Lett., 44, 1132–1140, doi:10.1002/2016GL071241.