Project: **1005**

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

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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 HPC 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 07/2018 to 06/2019, computing time has been spent to quantify the source uncertainties and direct radiative effects of BC aerosol in the Arctic region using the aerosol-climate model ECHAM6.3-HAM2.3 (Schacht et al., 2019). The model was upgraded to consider the BC-in-snow albedo reduction following Gilgen et al. (2018). Latest anthropogenic emissions were used from the ECLIPSE V5a database, comprising updated oil/gas industry losses and ship emission scenarios. As a further adaptation, high-resolved Russian BC emissions (Huang et al., 2015) were implemented. For the last decade (2005–2015), BC was modelled to contribute locally to the Arctic Amplification with an annual mean net direct radiative effect (DRE) of 0.4 $W\ m^{-2}$ at top of atmosphere (TOA). BC-induced albedo changes are regionally important with on average 0.2 $W\ m^{-2}$ in the Arctic (Figure 1). An evaluation of emission-related uncertainties revealed that: (i) actual daily instead of historic monthly biomass burning emissions are relevant to reproduce individual fire plumes but are not for the BC seasonal cycle; (ii) latest, transient anthropogenic emission data produces a 20% higher burden and up to 0.2 $W\ m^{-2}$ higher TOA DRE of BC in the central Arctic than a widely-used historic inventory; and (iii) regionally increased BC emissions in Russia improve the agreement with local measurements. Latest ground and airborne aerosol observations were used for model evaluation. Good agreement was found at surface level, but a systematic overestimation of modelled BC at altitudes above 500 hPa in summer (Figure 2). Over all, the current model version performs now better than the AeroCom average in terms of Arctic BC. The analysis of model uncertainties is continued with focus on aerosol ageing and wet removal.

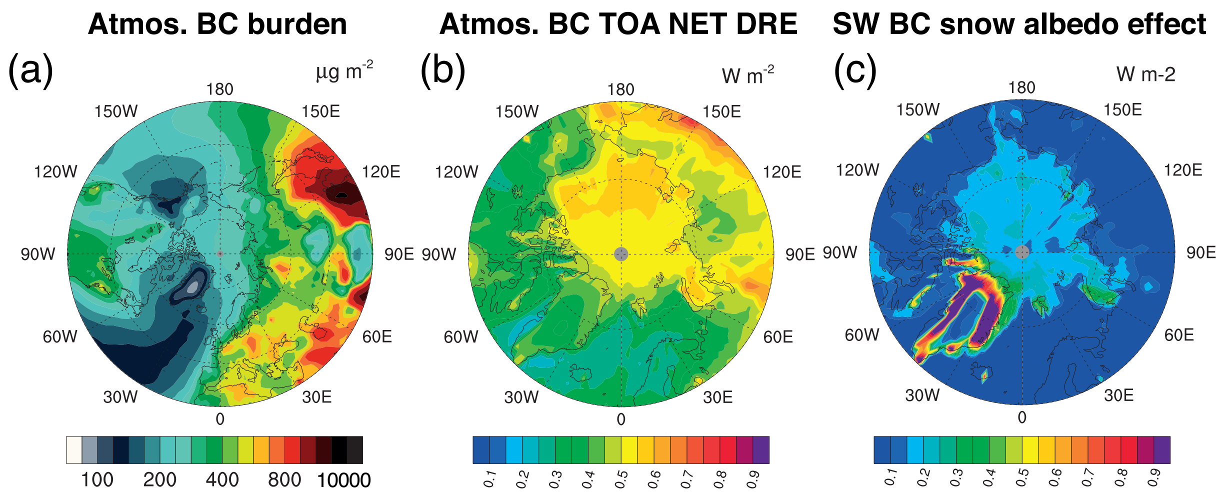

***Figure 1**: The 2005–2015 mean of (a) BC burden, (b) net all–sky direct radiative effect of BC at TOA, and (c) shortwave BC-in-snow albedo effect in the Arctic as computed with ECHAM6.3-HAM2.3 (Schacht et al., 2019).*

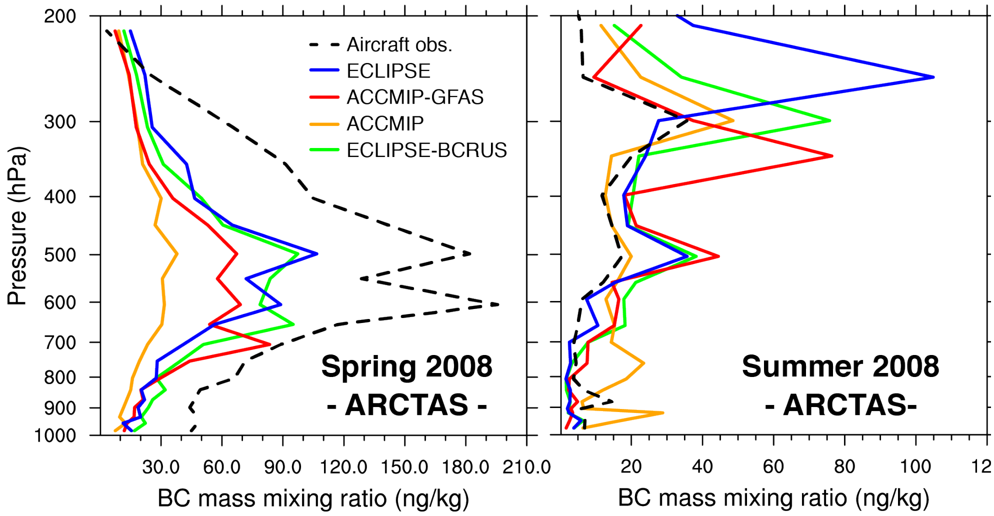

***Figure 2**: Vertical profiles of BC mass mixing ratios from airborne in-situ measurements during the flight campaign ARCTAS in April and June/July 2008, respectively. The modeled BC mass mixing ratios were averaged over the vertical levels. The black dashed lines show the observations, and colored lines indicate the results of the different ECHAM6.3-HAM2.3 runs using different emission inventories (Schacht et al., 2019).*

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 the follow-up project, these model uncertainties will be investigated with the help of the tagged BC tracers and sensitivity studies on model parameters controlling aerosol removal. The evaluation will in particular use aircraft measurements, which provide detailed information about the aerosol layering and properties.

Utilisation and Publication

This work contributes to the evaluation and further improvement of the latest model version ECHAM6.3-HAM2.3. The results have been presented at several science conferences and have recently been published in the open-access journal Atmospheric Chemistry and Physics Discussion. A second paper publication is currently in preparation.

References

Gilgen, A., Huang, W. T. K., Ickes, L., Neubauer, D., and Lohmann, U. (2018), How important are future marine and shipping aerosol emissions in a warming Arctic summer and autumn?, Atmos. Chem. Phys., 18, 10 521–10 555, https://doi.org/10.5194/acp-18-10521-2018.

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, J. Geophys. Res. – Atmos., 120(21), doi: 10.1002/2015JD023358.

Schacht, J., Heinold, B., Quaas, J., Backman, J., Cherian, R., et al. (2019), The importance of the representation of air pollution emissions for the modeled distribution and radiative effects of black carbon in the Arctic, Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2019-71.