Project: **1005**

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

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Report period: **2020-07-01 to 2022-06-30**

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 HPC project is to perform and evaluate the simulations with the global aerosol-climate model ECHAM6-HAM2 and the regional transport model COSMO-MUSCAT and since recently with the new aerosol-climate model system ICON-HAM, which 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.

In the project period 07/2020 to 06/2022, the modelling activities aimed to evaluate the uncertainty of the direct radiative effect (DRE) of black carbon (BC) with regard to the uncertainties due to the representation of aerosol microphysics and wet deposition in the aerosol-climate model ECHAM6.3-HAM2.3. This work builds on the progress made in improving the emissions setup during the previous allocation periods (Schacht et al., 2019; Hodzic et al., 2020). The model was upgraded with a tagging capability to track BC separately by source regions. Ultimately, a set of experimental 2-year runs with tagged tracers was performed with the goal to explain the overestimation of high-altitude Arctic BC found in earlier project phases (Schacht et al., 2019). The overestimation was found to be caused by long-range transported BC from the China region. A higher in-cloud wet scavenging combined with a slower ageing of aerosol particles was found to improve the model performance with regard to BC profiles in comparison to airborne measurements. During this allocation period the improvement of the representation of aerosol vertical layering could be finalised with a new configuration of aerosol ageing and wet removal parameters. Using the optimised configuration, several 12-year runs (2007-2018) were performed to estimate the difference in the transport and DRE of BC to the version used in Schacht et al. (2019). Based on this, ECHAM6.3-HAM2.3 simulations were analysed to quantify the key uncertainties limiting the accuracy of model estimates of Arctic BC and its radiative effects. Improved emission assumptions led to 25% higher, optimized aerosol ageing and wet removal to 10% lower Arctic BC burdens, each resulting in a more than 20% uncertainty in direct radiative forcing. We found a TOA direct (effective) radiative effect of atmospheric BC of +0.31 W m^{-2} (–0.2 W m^{-2}) and a BC-in-snow albedo effect of +0.12 W m^{-2}, averaged over the Arctic (>60°N) and 2007-2018 (Figure 1) (Wendisch et al., 2022).

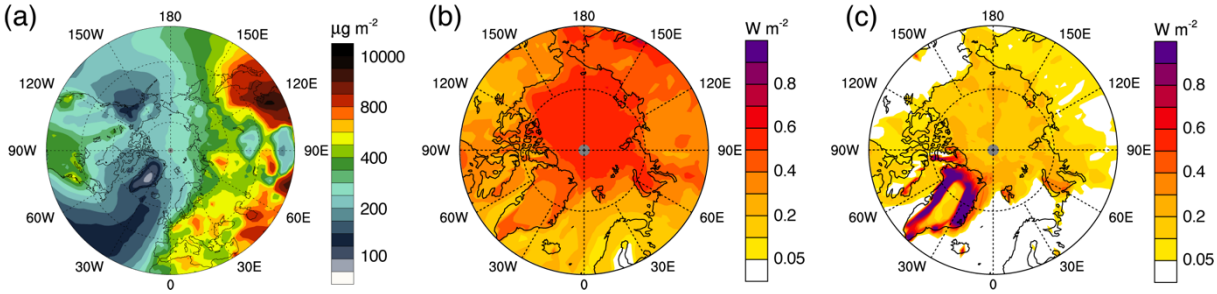

***Figure 1**: The 2007–2018 annual mean of (a) BC column burden, (b) net all–sky DRE of BC at TOA, and (c) solar BC-in-snow albedo effect in the Arctic as computed with ECHAM6.3-HAM2.3.*

During (AC)^3 phase 2, the focus of subproject D02 ('Modelling marine organic aerosol and its impact on clouds in the Arctic') has be extended to marine organic aerosol from the second half of year 2020. The aim is to explore whether the sea ice retreat will lead to an increase in oceanic aerosol production that can modulate the rapid Arctic warming through aerosol-cloud interactions. For this purpose, the ocean emission scheme in ECHAM6.3-HAM2.3 was further developed to consider species-group resolved marine organic aerosol (in particular cloud-active species) following the approach by Burrows et al. (2014). In addition, the parameterisation was ported to the new ICON-HAM model. Initial testing of ICON-HAM including the new scheme at R2B04 (~160 km) /L47 resolution for model periods of 2 to 10 years shows reasonable results within the range of previous studies. As expected, marine lipids dominate in highly bioactive oceanic regions, while proteins and polysaccharides contribute in less-productive waters and late blooms periods (Figure 2).

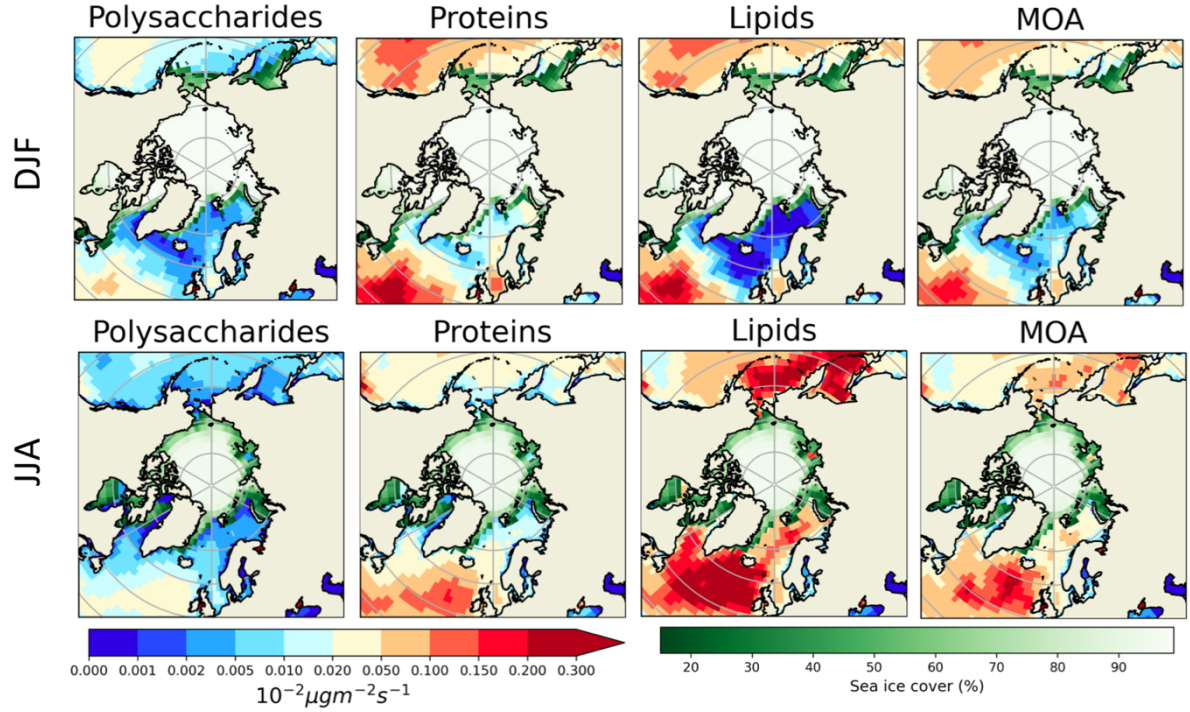

***Figure 2**: Seasonal mean emissions of Marine Primary Organic Aerosol (MOA) and key compounds (polysaccharides, proteins, lipids) computed by the aerosol-climate model ICON-HAM using the OCEANFILMS parameterization from S. Burrows (PNNL) for the period 2000–2010. A particular interest is in marine sugars, which are thought to have ice-nucleating properties and thus are relevant to climate and precipitation formation.*

Perspectives

In the coming allocation period, the new marine emission scheme in ICON-HAM will be further developed and thoroughly evaluated with available observations. The new marine organic aerosol tracers will be linked to cloud microphysics to study aerosol-cloud effects, and sensitivity experiments will be carried out with regard to the variability of marine aerosol production due to changes in Arctic sea ice over the last decade. The transition from HLRE-3 (Mistral) to the new HLRE-4 (Levante) is seen as a particular challenge.

References

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