Project: **1005**

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

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Report period: **2023-07-01 to 2024-06-30**

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 its successor ICON-HAM, which are used to investigate the sources and transport pathways of aerosols as well as their impact on Arctic climate. In the current project phase, the focus is on modelling marine organic aerosol and cloud effects. The aim is to explore whether the sea ice retreat will lead to an increase in oceanic aerosol production that can modulate Arctic warming by aerosol-cloud interactions.

In the previous allocation period, the ocean emission scheme in ECHAM6.3-HAM2.3 was expanded to consider species-group resolved marine organic aerosol (MOA) and especially cloud-active compounds. For this purpose, the module OCEANFILMS (Organic Compounds from Ecosystems to Aerosols: Natural Films and Interfaces via Langmuir Molecular Surfactants) module by S. Burrows (PNNL) was implemented, which describes the submicron organic mass fraction in sea spray aerosol. The new aerosol species were also linked to the cloud parameterisation. In parallel, this implementation was also carried out in ICON-HAM.

Since then, the computing time granted has been used to improve and comprehensively evaluate the emission scheme. It has been updated to utilise marine precursors as lower boundary conditions from current and future scenarios of the marine biogeochemical model FESOM2-REcoM2, developed by the Alfred Weger Institute (AWI) and applied with a 4.5 km pan-Arctic setup. The key components of primary MOA that are now considered in the aerosol-climate model are dissolved acidic polysaccharides (PCHO), dissolved combine amino acids (DCAA), and dissolved polar lipids (PL).

Comparisons of the modelled organic mass fractions (OMF) of the marine macromolecules in the sea spray aerosol with a series of sample measurements in different climate zones and regions of the world show good agreement (Figure 1). When the molecules are transferred from the sea surface to the aerosol phase, their respective contribution and seasonal occurrence changes depending on their physico-chemical properties. Here, the precursor concentrations are higher for PCHO than for DCAA and PL. However, PL contributes most to aerosol OMF due to its high surface affinity and accordingly high enrichment. The model reproduces this behaviour reasonably well, but the MOA concentrations are significantly underestimated in some regions (see, e.g., the data points in the southern and northern high latitudes and in the Baltic Sea in Figure 1). This is due to a partly considerable underestimation of sea salt production in the ECHAM6.3-HAM2.3 model, to which the MOA emissions are linked via the OMF. Overall, however, emissions and total burden of primary marine organic aerosol (MOA) are within the range of previous studies and reasonable in view of the uncertainties in the assumptions.

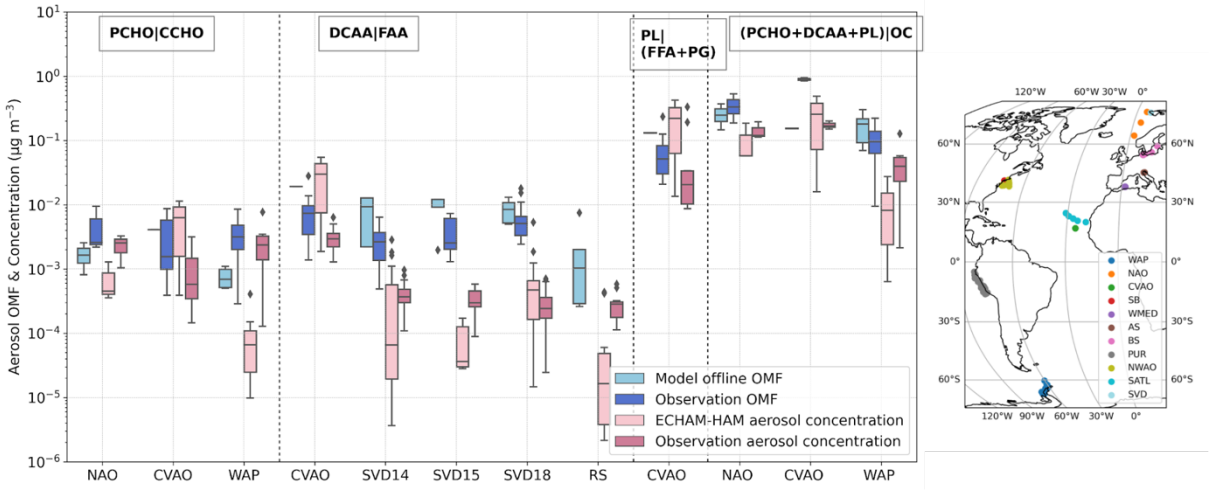

***Figure 1**: Offline computed organic mass fraction and ECHAM-HAM simulated concentration of PCHO, DCAA, PL, and their total for the stations on the map on the right. The colours coral and pink mark the modelled and blue and dark pink the observed values of OMF and aerosol concentration. Map: Locations of sea-water samples and marine aerosol measurements.*

In addition, the evaluation with aircraft measurements from the NASA ATom campaigns shows that the ECHAM6.3-HAM2.3 estimates of organic aerosol over remote oceanic regions are significantly improved when the primary MOA is included (Figure 2). These and other analysis results, as well as interesting findings on the latest trends in MOA and oceanic precursors in the Arctic, are planned for publication in early summer.

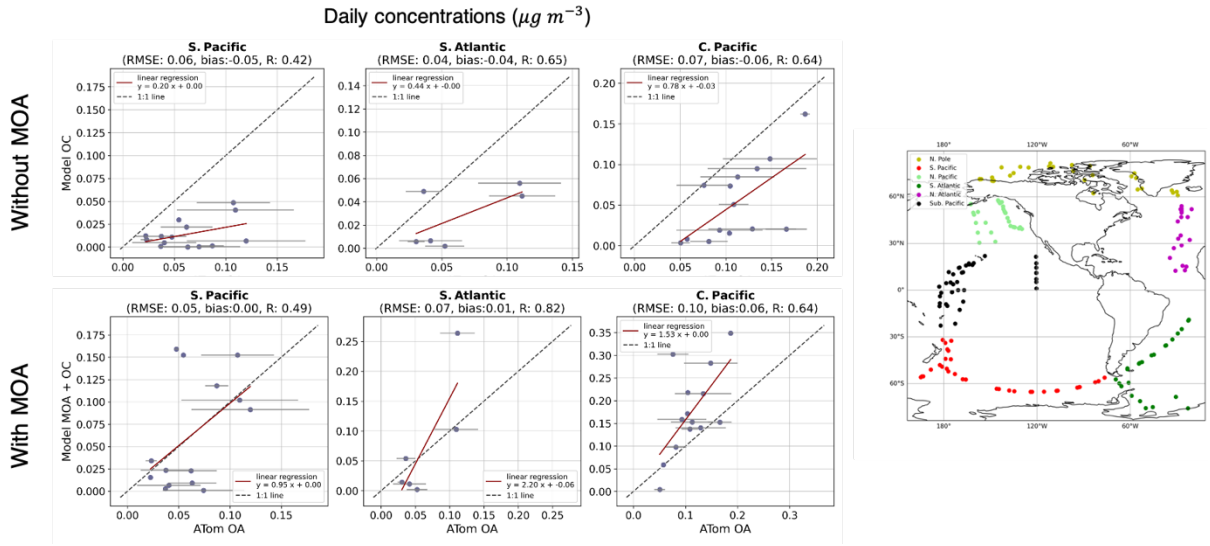

***Figure 2**: Scatter plots of organic aerosol (OA) concentrations from the NASA Atmospheric Tomography Mission (Atom; 2016 – 2018) compared to organic carbon (OC) as modelled by ECHAM6.3-HAM2.3 without and including primary MOA, respectively, shown for different remote oceanic regions. The range of values was limited to 0.3 μ gm^{-3} in order to restrict it to pristine conditions and to exclude wildfire plumes. Map: ATom flight tracks below 1 km, color coded by region. Inland data was filtered out to focus on the ocean/coast.*

Perspectives

In the coming allocation period, the new marine emission scheme in ECHAM-HAM/ICON-HAM will be used to investigate past and future trends in the distribution and variability of the key primary species of marine aerosol and their contribution to the budget of cloud condensation and freezing nuclei in the Arctic region.