Project: **1005**

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

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Report period: **2022-07-01 to 2023-06-30**

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.

A major part of the computing time granted for the report period was used for porting our models to the new HPC system Levante, which became available in mid-2022 while access to Mistral was closed. The two models ECHAM6-HAM2.3-MOZ1.0 and ICON-HAM required porting, performance tuning and extensive testing, which involved a lot of effort. Numerous test simulations were run, most of them covering model periods of up to six months.

Scientifically, the ocean emission scheme in ECHAM6.3-HAM2.3 was extended to consider species-group resolved marine organic aerosol (MOA) to consider especially cloud-active marine particles. The parameterisation was then ported to the ICON-HAM model, where it was further developed. 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 1).

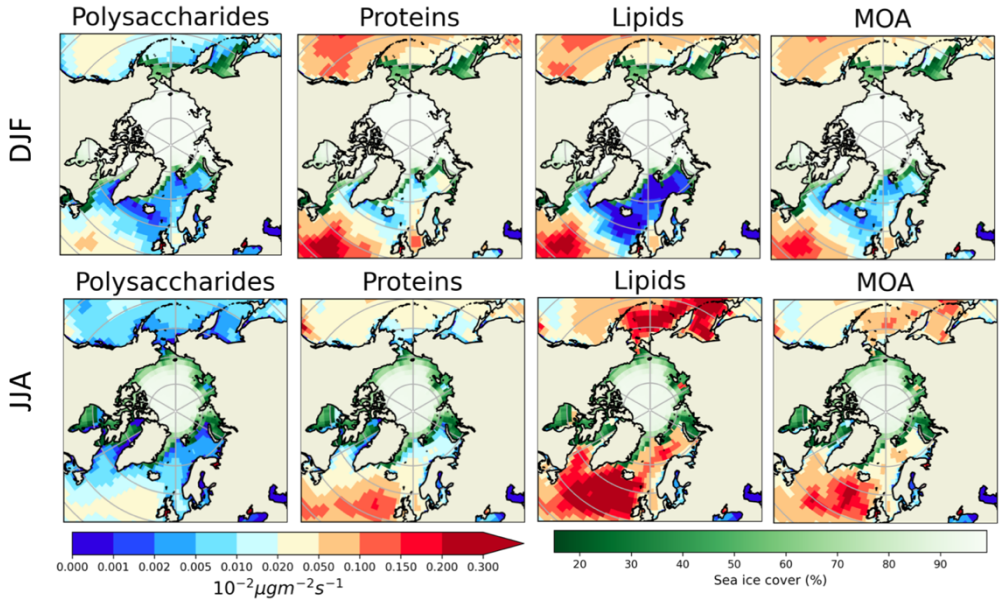

***Figure 1**: Seasonal mean emissions of Marine Primary Organic Aerosol (MOA) and key compounds (polysaccharides, proteins, lipids) computed by ICON-HAM using the OCEANFILMS parameterization from S. Burrows (PNNL) for the period 2000–2010.*

Recently, the activation of MOA and dust as ice-nucleating particles (INP) was implemented in ICON-HAM. According to the simulations, there is a significant contribution of MOA to the particles immersed in cloud droplets over the oceans in both hemispheres while dust predominates over northern continental areas. Particles immersed in droplets are more abundant in the accumulation mode than in the coarse mode. The ratio of immersed MOA and desert dust particles is dominated by over Southern Ocean throughout the year and in the Arctic boundary layer during late summer (Figure 2). This significant contribution of MOA to the total particles immersed in cloud droplets in the Arctic boundary layer suggests that MOA is potentially an important INP at relatively warm temperatures of around -10oC to -12oC. Currently, ICON-HAM is updated to use marine precursors from present-day and future simulations of the ocean–biogeochemical model FESOM2–REcoM2 with a 4.5 km pan–Arctic setup. It is expected that this will considerably improve the representation of marine organic aerosols emissions in ICON-HAM and enable the calculation of future scenarios.

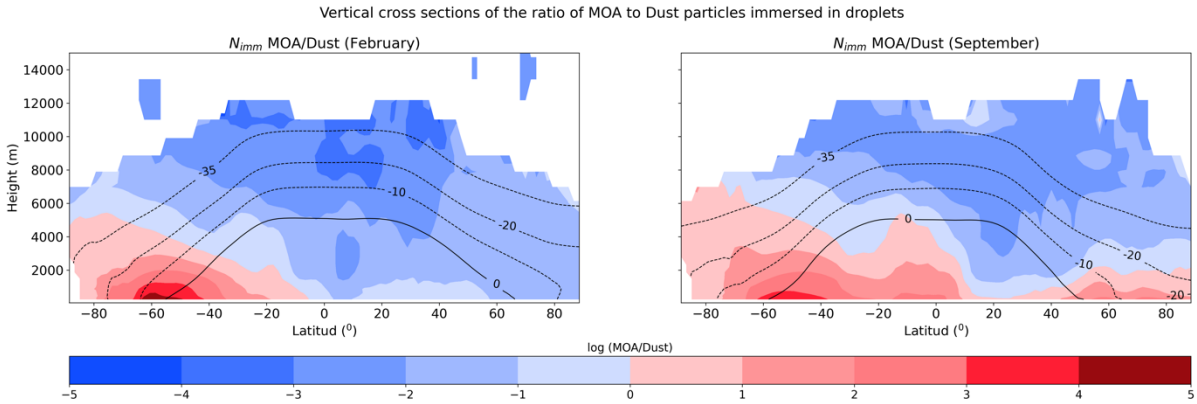

***Figure 2**: Vertical cross-sections of the zonal mean ratio of MOA to desert dust particles immersed in cloud droplets as computed by ICON-HAM including the OCEANFILMS parameterization for February and September 2010, respectively.*

Perspectives

In the coming allocation period, the new marine emission scheme in ICON-HAM will be further developed and thoroughly evaluated with available observations. Sensitivity experiments are planned with regard to the variability of marine aerosol production due to changes in Arctic Sea ice over the last decade.