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Ship Emission Influence on Clouds: A Sensitivity Assessment of ECHAM5-HAM

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Clouds are of importance in the climate system because of their interaction with the hydrological cycle and the radiant energy flow. Anthropogenic activities come in hand with emissions of aerosols and aerosol precursor gases, making the quantification of their impact on cloud properties, e.g. cloud droplet number concentration, cloud lifetime or even cloud top height, a topic of ongoing research. Aerosol influence on cloud micro- and macrophysical properties are referred to as aerosol indirect effects and are subject to the largest uncertainties of all radiative forcing components of the Earth System when it comes to assessing human induced climate change. Seagoing ships are the least regulated sources of anthropogenic emissions, burning low-quality residual fuels containing high amounts of sulfur or even heavy metals. Combustion of such fuels produces, aside from gaseous species, large amounts of particulate matter (PM) consisting of elemental (black) and organic carbon, sulfate, ash and particles forming from sulfuric acid. The emitted particles can serve as cloud condensation nuclei (CCN) leading to aerosol indirect effects.

In this study, we investigate the sensitivity of aerosol indirect effects as calculated by the ECHAM5-HAM aerosol-climate model with respect to ship emissions. The model is run for seven years (including a two year spinup, five years averaging for results) with a spatial resolution of 2.8° x 2.8° and prescribed sea surface properties (AMIP). We use parametrizations of aerosol cloud interactions to investigate aerosol indirect effects. Aerosol emissions from ships are provided by the recently compiled QUANTIFY emission inventory. The sensitivity runs performed use the emission of black carbon (BC) and sulfur dioxide (SO_2) increased by a factor of 10(100), enabling a focus on the aerosol-cloud interactions when the marine boundary layer composition is significantly disturbed. Furthermore, experiments using increased BC(SO_2) and unchanged SO_2(BC) emissions are performed to analyse component specific sensitivity. Dependency of calculated aerosol indirect effects on model resolution is also investigated.

Results show, that spatial patterns of changes in cloud micro- and macrophysical properties as well as radiative effects do not indicate the presence of elevated levels of aerosol burdens in shipping corridors on global oceans. It is by an increase of the emissions by a factor of 10 that patterns begin to show. These are enhanced when increasing the emissions by a factor of 100. As expected, effects on cloud properties are significantly dependent on the presence of soluble particles and can only be depicted when artificially high ship emissions are implemented in the model. This hints at the necessity to further investigate and modify the parametrization of the interaction of ship emitted particles and trace gases.