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Simulating the Earth system with interactive aerosols at the kilometer scale

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Aerosols originate from natural processes and human activities. They scatter and absorb radiation but also act as condensation nuclei in clouds. How these interactions influence the climate is still uncertain. New climate simulations at the kilometer-scale allow us to examine long-standing questions related to these interactions such as the complex effects on convective clouds. To perform kilometer-scale simulations with interactive aerosols, we developed the reduced-complexity aerosol module HAM-lite and coupled it to the climate model ICON-Sapphire. HAM-lite is based on and fully traceable to the complex aerosol module HAM. Aerosols are represented as an ensemble of log-normal modes with prescribed sizes and compositions.

We present first global simulations with ICON-Sapphire and HAM-lite at resolutions of about five kilometers and over periods of a few months. The sea surface temperature and sea ice are prescribed with boundary conditions of AMIP, and the initial conditions of the atmosphere and land are derived from the operational analysis of ECMWF. The aerosols are represented by two pure modes, one of dust and one of sea salt, and two internally mixed modes, both of organic carbon, black carbon, and sulfate. The first mixed mode represents aerosols from biomass burning emissions and the second mixed mode represents aerosols from anthropogenic and volcanic emissions.

The simulations capture key elements of the global aerosol cycle, of which some are missing entirely in coarse-scale simulations. For example, cold pool fronts drive intense dust storms over the Sahara and tropical cyclones interact with sea salt aerosols in the Pacific. We observe the transport of dust aerosols across the ocean, the wash out of sea salt aerosols by rain bands, and the updraft of biomass burning aerosols over land. We evaluate the observations with a combination of remote-sensing and in-situ data. We also compare the results to coarse-scale climate simulations. To understand processes like updraft by convection or deposition by rain, we examine the distribution of aerosols throughout the vertical column.