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The evolution of the global aerosol system in a transient climate simulation from 1860 to 2100

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Abstract. The evolution of the global aerosol system from 1860 to 2100 is investigated through a transient atmosphere-ocean General Circulation Model climate simulation with interactively coupled atmospheric aerosol and oceanic biogeochemistry modules. The microphysical aerosol module HAM incorporates the major global aerosol cycles with prognostic treatment of their composition, size distribution, and mixing state. Based on an SRES A1B emission scenario, the global mean sulfate burden is projected to peak in 2020 while black carbon and particulate organic matter show a lagged peak around 2070. From present day to future conditions the anthropogenic aerosol burden shifts generally from the northern high-latitudes to the developing low-latitude source regions with impacts on regional climate. Atmospheric residence- and aging-times show significant alterations under varying climatic and pollution conditions. Concurrently, the aerosol mixing state changes with an increasing aerosol mass fraction residing in the internally mixed accumulation mode. The associated increase in black carbon causes a more than threefold increase of its co-single scattering albedo from 1860 to 2100. Mid-visible aerosol optical depth increases from pre-industrial times, predominantly from the aerosol fine fraction, peaks at 0.26 around the sulfate peak in 2020 and maintains a high level thereafter, due to the continuing increase in carbonaceous aerosols. The global mean anthropogenic top of the atmosphere clear-sky short-wave direct aerosol radiative perturbation intensifies to -1.1 W m^{-2} around 2020 and weakens after 2050 to -0.6 W m^{-2}, owing to an increase in atmospheric absorption. The demonstrated modifications in the aerosol residence- and aging-times, the microphysical state, and radiative properties challenge simplistic approaches to estimate the aerosol radiative effects from emission projections.

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