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Resolving the mixing state of ice nuclei with EMAC/MADE-IN

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Specific types of mineral dust and black carbon (BC) particles can nucleate ice crystals at lower supersaturations than those needed for liquid particles to freeze. The number concentration of such particles, called ice nuclei (IN), is usually small and can therefore limit the number of growing ice crystals. When released, most IN are externally mixed with other aerosol compounds. Through coagulation and condensation of gases, they obtain a coating and become internally mixed. The mixing state of IN influences their ability of initiating ice nucleation, as well as their radiative and hygroscopic properties.

We report on the development and application of the new aerosol microphysics submodel MADE-IN, implemented within the ECHAM/MESSy Atmospheric Chemistry global model (EMAC). MADE-IN tracks mass and number concentrations of BC and dust particles in their different mixing states, as well as BC- and dust-free particles. We applied EMAC/MADE-IN to study global distribution and properties of potential atmospheric IN, focusing on their number concentration and mixing state in the UTLS. Our simulations show that only about 0.1 to 10 particles/cm^3 in the UTLS contain BC or dust, representing a very small fraction of the total aerosol number concentration. Nearly all potential IN in the UTLS are internally mixed with soluble material. An investigation on the role of the individual aging processes showed that condensation of sulfate is the most effective one. The resulting e-folding aging time scales of externally mixed BC and dust show a very high horizontal and vertical variability with values in the northern hemisphere between 0.5 and 5 hours close to the surface and up to 4 days in the UTLS region. This is in contrast to the current usage in many global models where the aging time scales for BC are assumed to be constant with values of around 1 or 2 days.