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An aerosol chamber investigation of the heterogeneous ice nucleating potential of refractory nanoparticles

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Abstract. Nanoparticles of iron oxide (crystalline and amorphous), silicon oxide and magnesium oxide were investigated for their propensity to nucleate ice over the temperature range 180–250 K, using the AIDA chamber in Karlsruhe, Germany.

All samples were observed to initiate ice formation via the deposition mode at threshold ice super-saturations (RHi_{thresh}) ranging from 105% to 140% for temperatures below 220 K. Approximately 10% of amorphous Fe_2O_3 particles (modal diameter = 30 nm) generated in situ from a photochemical aerosol reactor, led to ice nucleation at RHi_{thresh} = 140% at an initial chamber temperature of 182 K. Quantitative analysis using a singular hypothesis treatment provided a fitted function [$n_s(190\text{ K})=10^{(3.33\times s_{ice})+8.16}$] for the variation in ice-active surface site density (n_s:m^{-2}) with ice saturation (s_{ice}) for Fe_2O_3 nanoparticles. This was implemented in an aerosol-cloud model to determine a predicted deposition (mass accommodation) coefficient for water vapour on ice of 0.1 at temperatures appropriate for the upper atmosphere. Classical nucleation theory was used to determine representative contact angles (θ) for the different particle compositions. For the in situ generated Fe_2O_3 particles, a slight inverse temperature dependence was observed with θ = 10.5° at 182 K, decreasing to 9.0° at 200 K (compared with 10.2° and 11.4° respectively for the SiO_2 and MgO particle samples at the higher temperature).

These observations indicate that such refractory nanoparticles are relatively efficient materials for the nucleation of ice under the conditions studied in the chamber which correspond to cirrus cloud formation in the upper troposphere. The results also show that Fe_2O_3 particles do not act as ice nuclei under conditions pertinent for tropospheric mixed phase clouds, which necessarily form above ~233 K. At the lower temperatures (<150 K) where noctilucent clouds form during summer months in the high latitude mesosphere, higher contact angles would be expected, which may reduce the effectiveness of these particles as ice nuclei in this part of the atmosphere.

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