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Possible influence of anthropogenic aerosols on cirrus clouds and anthropogenic forcing

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Abstract. Cirrus clouds have a net warming effect on the atmosphere and cover about 30% of the Earth's area. Aerosol particles initiate ice formation in the upper troposphere through modes of action that include homogeneous freezing of solution droplets, heterogeneous nucleation on solid particles immersed in a solution, and deposition nucleation of vapor onto solid particles. Here, we examine the possible change in ice number concentration from anthropogenic soot originating from surface sources of fossil fuel and biomass burning, from anthropogenic sulfate aerosols, and from aircraft that deposit their aerosols directly in the upper troposphere. We use a version of the aerosol model that predicts sulfate number and mass concentrations in 3-modes and includes the formation of sulfate aerosol through homogeneous binary nucleation as well as a version that only predicts sulfate mass. The 3-mode version best represents the Aitken aerosol nuclei number concentrations in the upper troposphere which dominated ice crystal residues in the upper troposphere. Fossil fuel and biomass burning soot aerosols with this version exert a radiative forcing of -0.3 to -0.4 Wm^{-2} while anthropogenic sulfate aerosols and aircraft aerosols exert a forcing of -0.01 to 0.04 Wm^{-2} and -0.16 to -0.12 Wm^{-2}, respectively, where the range represents the forcing from two parameterizations for ice nucleation. The sign of the forcing in the mass-only version of the model depends on which ice nucleation parameterization is used and can be either positive or negative. The magnitude of the forcing in cirrus clouds can be comparable to the forcing exerted by anthropogenic aerosols on warm clouds, but this forcing has not been included in past assessments of the total anthropogenic radiative forcing of climate.

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