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On the transition between heterogeneous and homogeneous freezing

K. Gierens
Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

Abstract. Box model simulations of an uplifting and adiabatically cooling cloud of aerosol have been performed in order to study the transition between cirrus formation dominated by homogeneous nucleation of ice to that dominated by heterogeneous nucleation. The aerosol was assumed to consist of an internal mixture of sulfuric acid solution droplets with inclusions of soot. The parametrisation of De Mott et al. (1997) was used to simulate the heterogeneous nucleation of ice in such droplets with soot inclusions. The simulations show that the transition from heterogeneous to homogeneous nucleation occurs over a narrow range of soot concentration. Thus it seems to be possible to fix critical concentrations of heterogeneous ice nuclei which must be exceeded if heterogeneous freezing dominates cirrus formation. A formula has been derived that allows to compute the critical concentrations of heterogeneous ice nuclei as a function of temperature, updraft speed, ambient pressure, and supersaturation at which heterogeneous freezing occurs. Generally, homogeneous nucleation dominates in regions with updrafts stronger than 20 cm s^{-1}, with the exception of heavily polluted areas which could be common in the northern hemisphere due to air traffic, where updrafts of the order 1 m s^{-1} may be necessary to render heterogeneous nucleation unimportant. According to the present results it cannot be excluded that heterogeneous nucleation plays a more important role for cirrus formation in the northern midlatitudes than anywhere else. A possible consequence of these results is that air pollution may lead to a higher coverage of cirrus clouds, but then these clouds will be optically thinner than clouds formed by homogeneous freezing, with the exception of regions where condensation trails are frequent.

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