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Cirrus clouds as seen by the CALIPSO satellite and ECHAM-HAM global climate model

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Ice clouds impact the planetary energy balance and upper tropospheric water vapour transport and are therefore relevant for climate. In this study ice clouds at temperatures below -40°C simulated by the ECHAM-HAM global climate model are compared to CALIPSO/CALIOP satellite data. The model reproduces well the mean occurrence of ice clouds, while the ice water path, ice crystal radius, cloud optical depth and extinction are overestimated in terms of annual means and temperature dependent frequency histograms. Two distinct types of cirrus clouds are found: in-situ formed cirrus dominating at temperatures below -60°C and liquid-origin cirrus, dominating at temperatures warmer than -55°C. The latter form in anvils of deep convective clouds or by glaciation of mixed-phase clouds. They are associated with ice water contents of up to 0.1 $\mathrm{g\,m^{-3}}$ and extinctions of up to 0.1 $\mathrm{km^{-1}}$, while the in-situ formed cirrus are optically thinner and contain at least an order of magnitude less ice. The ice cloud properties do not differ significantly between the southern and the northern hemisphere.
In-situ formed ice clouds are further divided into homogeneously and heterogeneously nucleated ones. The simulated liquid-origin ice crystals mainly form in convective outflow in large number concentrations, similar to in-situ homogeneously nucleated ice crystals. On the contrary, heterogeneously nucleated ice crystals are associated with smaller number concentrations. However, ice crystal aggregation and depositional growth smooth the differences between several formation mechanisms making the attribution to a specific ice nucleation mechanism challenging.