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Ice supersaturations and cirrus cloud crystal numbers

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Abstract. Upper tropospheric observations outside and inside of cirrus clouds indicate water vapour mixing ratios sometimes exceeding water saturation. Relative humidities over ice (RH_{ice}) of up to and more than 200% have been reported from aircraft and balloon measurements in recent years.

From these observations a lively discussion continues on whether there is a lack of understanding of ice cloud microphysics or whether the water measurements are tainted with large uncertainties or flaws.

Here, RH_{ice} in clear air and in ice clouds is investigated. Strict quality-checked aircraft in situ observations of RH_{ice} were performed during 28 flights in tropical, mid-latitude and Arctic field experiments in the temperature range 183–240 K. In our field measurements, no supersaturations above water saturation are found. Nevertheless, super- or subsaturations inside of cirrus are frequently observed at low temperatures (<205 K) in our field data set. To explain persistent RH_{ice} deviating from saturation, we analysed the number densities of ice crystals recorded during 20 flights. From the combined analysis – using conventional microphysics – of supersaturations and ice crystal numbers, we show that the high, persistent supersaturations observed inside of cirrus can possibly be explained by unexpected, frequent very low ice crystal numbers that could scarcely be caused by homogeneous ice nucleation. Heterogeneous ice formation or the suppression of freezing might better explain the observed ice crystal numbers.

Thus, our lack of understanding of the high supersaturations, with implications for the microphysical and radiative properties of cirrus, the vertical redistribution of water and climate, is traced back to the understanding of the freezing process at low temperatures.

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