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Observations of contrail cirrus in ice-subsaturated environments and implications for mitigating the climate impact of aviation

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Contrail cirrus, including line-shaped contrails, cause a net warming effect to the Earth's climate. Of great importance to estimate their radiative effect is the coverage and mean optical thickness, which are closely associated with the conditions affecting the formation and microphysical properties of contrail cirrus.

This study focuses on contrail cirrus observations over central Europe and the Northeast Atlantic from the airborne ML-CIRRUS campaign in 2014. To identify contrail cirrus in the dataset of cloud observations, the following method is used: (1) the Schmidt-Appleman-Criterion is calculated, determining whether the environmental conditions are suitable for contrail formation, (2) an aircraft plume detection algorithm is adapted, identifying if a measured air mass originated from aircraft exhaust and (3) based on (1) and (2), statistical analyses are performed, resulting in a description of the general characteristics of contrail and natural cirrus.

Applying this method, not only are contrail cirrus and natural cirrus separated by their different microphysical properties (mean mass radius, ice crystal number and ice water content), but the favorable spatial occurrence conditions of contrail cirrus are also detected: Contrail cirrus occur with rather high frequency at the cruising altitude, where the atmospheric pressure ranges from 200 to 245 hPa (ambient temperature 207 – 218 K). Of particular interest is the occurrence of contrail cirrus in slightly ice-subsaturated environments, where the relative humidity with respect to ice (RH_{ice}) centers around 90 % instead of ice supersaturation as believed hitherto. This also differs from the in-cloud RH_{ice} centering at 100 % in natural cirrus. Inspecting the occurrence frequency of air masses with RH_{ice} > 90 % in comparison to RH_{ice} > 100 % from passenger aircraft observations above Europe and the North Atlantic during the IAGOS-MOZAIC period from 1995 to 2010, about 45 % of the air masses are prone to contrail cirrus formation instead of 30 % found in merely ice-supersaturated environments. Considering this finding in the routing of passenger flights, the avoidance of slightly ice-subsaturated to ice-supersaturated conditions might lead to a reduction of the occurrence of contrail cirrus and thus to a possible mitigation of their climate

impact.

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