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The lifecycle and climate-impact of contrail cirrus

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The lifecycle of contrail cirrus has to be understood as a prerequisite to compute its weather and climate impact for given airtraffic and meteorology.

As a new concept, this study distinguishes between:

1) Externally limited contrail cirrus, where contrails form in moderately ice-supersaturated air, but ice particles stay small and contrails end by sublimation because of drying of the ambient air, e.g., when the ambient air subsides;

2) Internally limited contrail cirrus, where contrails form at high humidity with strong supersaturation or form in rising air masses, so that the ice particles grow until their fall speed gets large, and the ice particles finally fall to lower levels (e.g. in fall streaks).

For both kinds of contrail cirrus, scaling laws are set up which show how the "Surface Forcing" (SF), i.e. the time-integral of optical depth times width (integral of ice particle number per flight distance times ice particle cross-section area times extinction efficiency) depends on the lifetime, on the number of ice particles per unit length, ambient humidity, uplift velocity, wind shear, turbulent mixing, and temperature. SF can be converted into an energy forcing (EF), from which the global radiative forcing can be evaluated, for given radiative Earth-atmosphere properties and traffic density.

The scaling laws are tested by comparison to global contrail simulations with the most recent version of CoCiP (as in Schumann, 2012; and some changes), using ECMWF data and a global traffic data bases (ACCRI). The model assumes that contrail ice particles form initially mainly on soot, that the ice particles consume the ice supersaturation in the contrail plume, that the ice particle number decreases slightly with lifetime, and that interactions of contrails with ambient cirrus are weak. The scaling laws and the model allow estimating the climate impact of contrails as a function of a given aircraft and weather parameters.

The results are compared to available results from airborne observation campaigns, like CONCERT and MLCIRRUS, from remote sensing, from large eddy simulations and global model studies.

For externally limited contrails, the climate impact of contrails increases with about the square of the externally controlled lifetime and the third root of the number contrail ice particles per flight distance. For internally limited contrails, SF grows about linearly with this number.