Measurements of short-lived contrails embedded in subvisible cirrus clouds

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Overview

Aircraft contrails frequently occur in the upper troposphere. They consist of ice particles having the potential to directly affect the Earth's climate. The frequency, life time, ice crystal size spectra and thus radiative properties of contrails depend strongly on the ambient distribution of the relative humidity with respect to ice (RH_{ice}). In air with RH_{ice} below 100 % contrails are believed to be short-lived, while persistent contrails require an ambient RH_{ice} of at least 100 % (Gao et al., 2006, Atmospheric Environment).

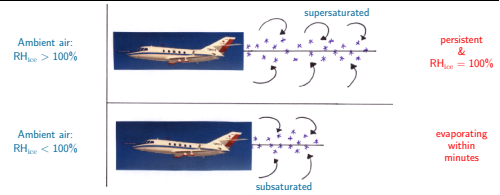
During the mid-latitude aircraft experiment CONCERT 2008 (CONtrail and Cirrus ExpeRimenT), RH_{ice} inside of contrails were measured using the high precision 'Fast In situ Stratospheric Lyman-α Hygrometer' FISH. The ice crystal size distribution in the size range d_{ice} = 2 - 1000 μm is recorded simultaneously using an FSSP ('Forward Scattering Spectrometer Probe'), a CPI ('Cloud Particle Imager) and a 2D-C (2D-Cloudprobe). We here present results from about 1.7 hours of observation time during 6 flights.

Most of the observed contrails are short-lived, i.e the ambient air was subsaturated. Nevertheless, ice crystals > 200 μm were detected inside of the contrails, contradicting our understanding that contrails consist of a high number of small ice crystals.

However, analysis of the vertical structure of the atmosphere indicate that the contrails were embedded in subvisible cirrus clouds.

Simulations with the kinetical microphysical model MAID reproduce the conditions leading to large ice crystal formation, showing that 200 μm ice crystals form only at very low cooling rates (~ 0.36 K/hour) typical for frontal systems, the typical weather situation during CONCERT. In contrast, during contrail formation very high cooling rates (~ 360 K/sec) predominate.

Relative Humidities in Contrails



Scheme of expected relative humidities over ice (RH_{ice}) in contrails

RH_{ice} observations in mid-latitude contrails

Campaign

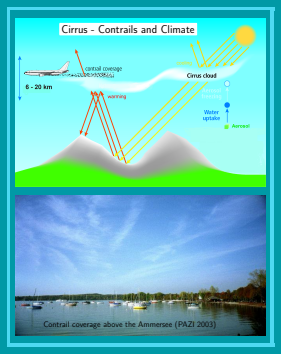
CONCERT 2008 6 flights

Measurements

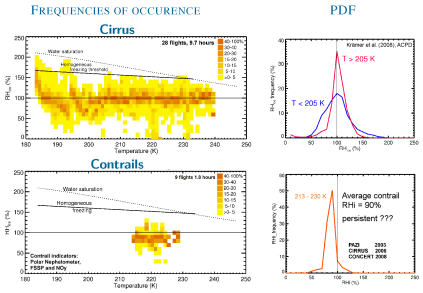
Aircraft:	DLR Falcon
Water:	FISH (Lyman α Hygrometer)
Ice crystals:	Polar Nephelometer, FSSP, 2D-C, CPI size range up to several 100 μm
Contrail indicator:	NOy detector

Contrail observations

210-230 K
8-11 km
1.7 h observation time



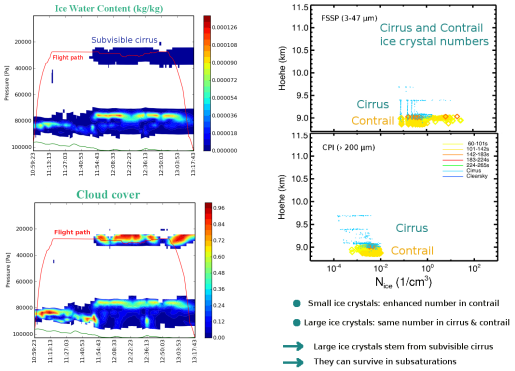
Cirrus & Contrail RH_{ice}



During CONCERT contrails were detected in subsaturated ambient air.
The typical weather situations were frontal systems.

CONCERT Flight 17. 11. 2008

Chasing contrail of Airbus A340



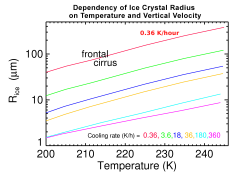
- Small ice crystals: enhanced number in contrail
- Large ice crystals: same number in cirrus & contrail
- Large ice crystals stem from subvisible cirrus
- They can survive in subsaturations

Large ice crystals in contrails

entrained from surrounding subvisible cirrus

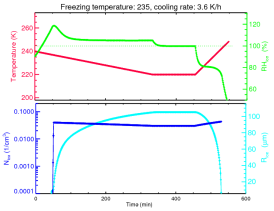
Large ice crystal formation

Model studies with kinetical microphysical model MAID



Large ice crystals emerge only at very low cooling rates typical for front cirrus.

Contrails form at very high cooling rates!
→ about 360 K/sec



Subvisible ice clouds with large ice crystals have LONG formation and evaporation times.