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

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Shaping Change

Motivation

- Aviation: ≈ 5% of the human-induced global warming (Lee et al., 2009 & 2021).
- Contrail cirrus: > 50% of aviation's climate forcing (Lee et al., 2009 & 2021).

  → Large uncertainties related to optical properties.

  → Complications concerning the differentiation from natural cirrus.

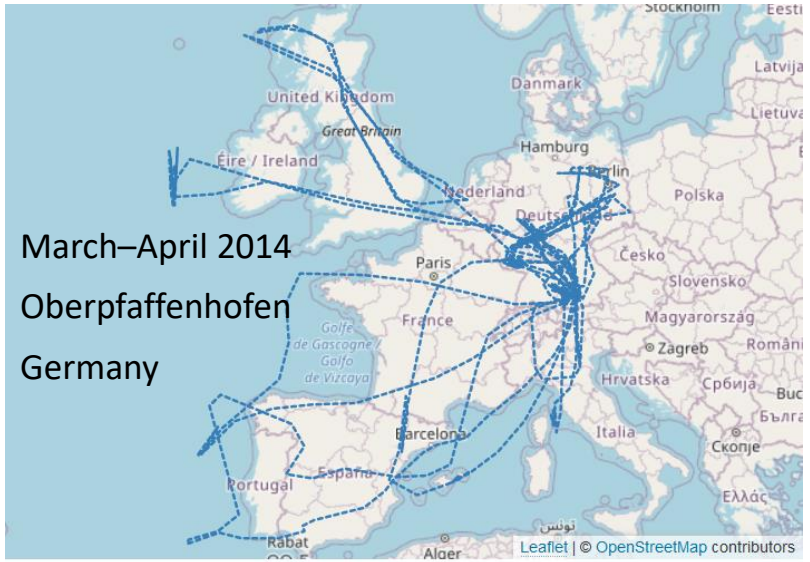
  → The importance of slight ice-subsaturation (Kübbeler et al., 2011) often neglected.

Investigation

The ML-CIRRUS 2014 dataset — 14.7 hrs contrail and natural cirrus sampling over Europe and the Northeast Atlantic region.

→ Separating contrail cirrus from natural cirrus.

→ Searching for the patterns in the occurrence of contrail cirrus.



Source: HALO database

Method

Separating contrail and natural cirrus:

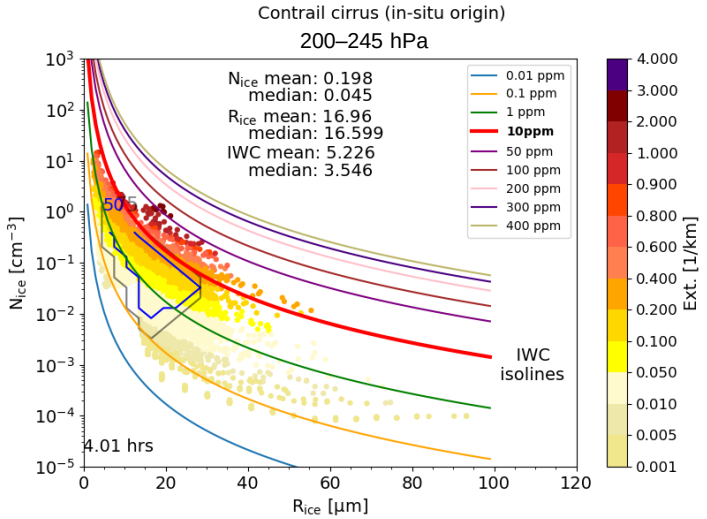
- T < 235 K & p < 350 hPa (altitude > ~ 8.1 km)
- The Schmidt-Appleman Criterion (SAC)
  - SAC fulfilled -> **contrail cirrus**, presumably
  - SAC unfulfilled -> **natural cirrus**
- The most frequent cruising altitude
  - 200–245 hPa, IAGOS statistics
- Statistical analysis

$$\text{Ext. } [\text{km}^{-1}] = A\,[mm^3/g] \times \frac{IWC\ [g/m^3]}{D_{eff}\ [\mu m]}$$

(Gayet et al., 2004)

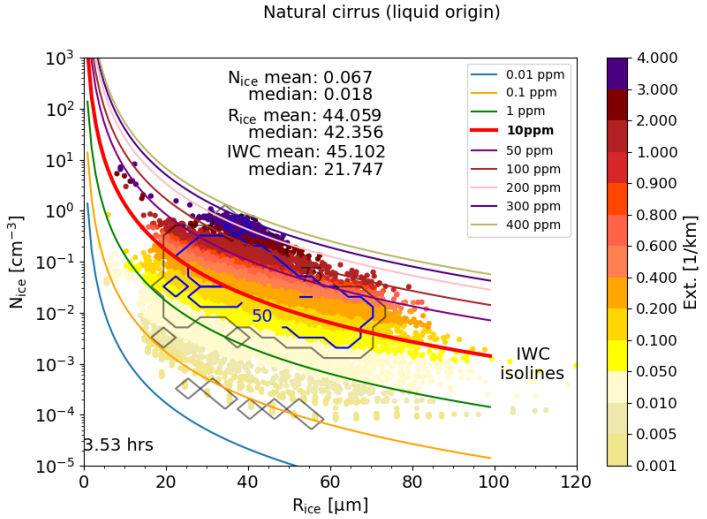
Results

1. Properties of contrail cirrus and liquid origin cirrus



Contrail cirrus often occur with:

R_{ice} < 30 µm
N_{ice} median = 0.045 cm^{-3}
IWC < 10 ppmv
Optically thin
Aged contrail cirrus

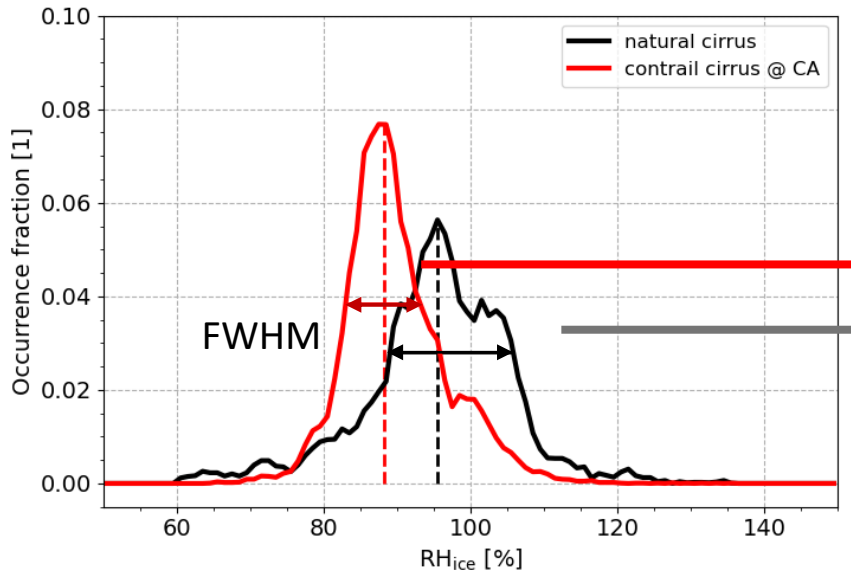


Liquid origin natural cirrus often occur with:

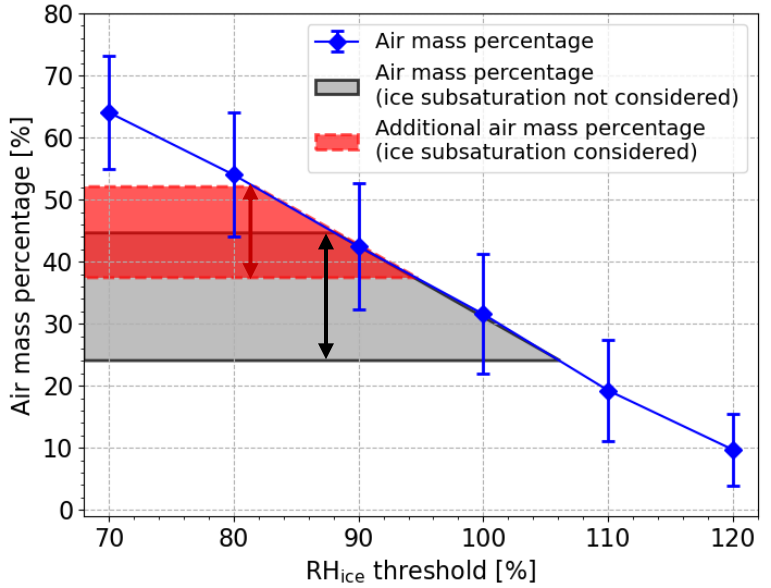
R_{ice} > 30 µm
N_{ice} median = 0.018 cm^{-3}
IWC > 10 ppmv
Optically thick

Results

2. Slight ice-subsaturation in contrail cirrus



ML-CIRRUS dataset: Probability distribution of RH_{ice} for contrail and natural cirrus.



MOZAIC dataset 1995 – 2010: Air mass fraction above Europe and the North Atlantic for different RH_{ice} threshold values.

- ✈ The fraction of air masses potentially contributing to contrail cirrus formation increases by ~ 8% if contrail cirrus in ice-subsaturation considered.

→→ Larger impact of contrail cirrus' radiative forcing ? — ongoing discussions and investigations

Summary

- ✓ A simple method to differentiate contrail cirrus and natural cirrus on a statistical basis.
- ✓ Microphysical and optical properties of contrail cirrus and natural cirrus measured during the ML-CIRRUS 2014 campaign.
- ✓ High occurrence probabilities of contrail cirrus over Europe and the Northeast Atlantic:
  - in the cruising altitude range — 200–245 hPa.
  - slight ice-subsaturation with RH_{ice} centring at ~ 90%.
- ✓ Implications for mitigating the climate impact of aviation:
  - Contrail cirrus' climate impact might be larger than previously thought.
  - Contrail avoidance might need to be conducted with a lower RH_{ice} threshold.

Thank you for your attention !