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Observations of Microphysical Properties and Radiative Effects of Contrail Cirrus and Natural Cirrus over the North Atlantic

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Motivation

Aircraft-induced clouds (AIC) represent the largest aviation radiation forcing (RF), with open issues on microphysical properties and radiative effects

- The **difference** between AIC and natural cirrus
- The **evolution of contrails** into **contrail cirrus**
- The accuray of top of atmosphere (TOA) shortwave **(SW) RF**

Data and approaches

- Experimental aspect
  - Airborne data from the HALO aircraft in **ML-CIRRUS (26.03.2014)** *(Voigt et al., 2017)*
  - Microphysical properties from **CiPS** (thin cirrus) *(Strandgren et al., 2017)* applied to MSG satellite
  - ERA5 trace gas and natural cloud profiles

- **Radiative transfer model (RTM)**
  - **Libradtran** *(Mayer and Kylling, 2005)* calculations

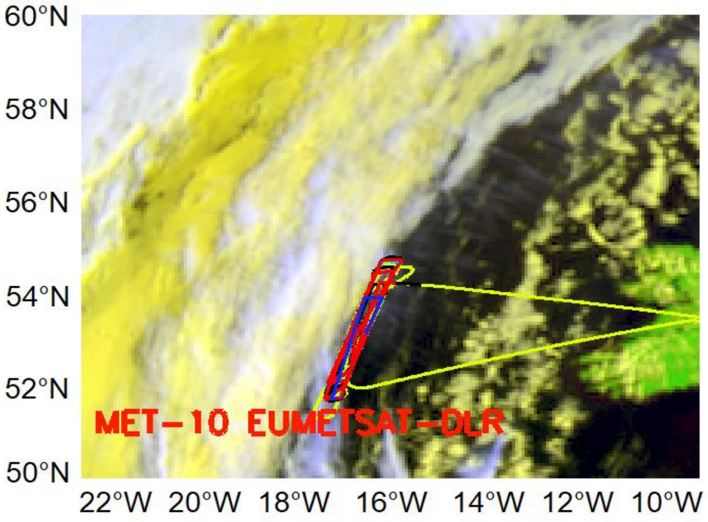

Fig.1 HALO track with measured natural cirrus (black), contrail cirrus (red) and contrails (blue) on top of a RGB on 26 March 2014

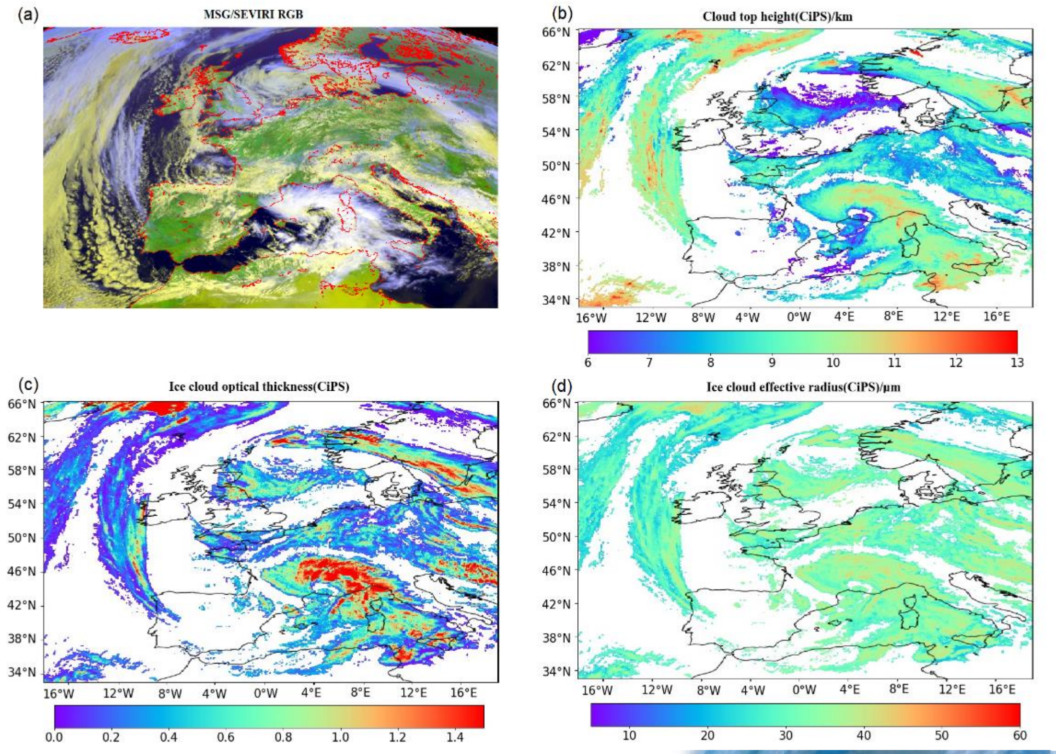

Fig.2 Cirrus mask and properties retrieved from MSG at 10:45 UTC

- Validation aspect
  - Reflected solar radiation (RSR) and outgoing longwave radiation (OLR) from **RRUMS** *(Vázquez-Navarro et al., 2013)* and GERB

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Microphysical Properties of AIC and natural cirrus

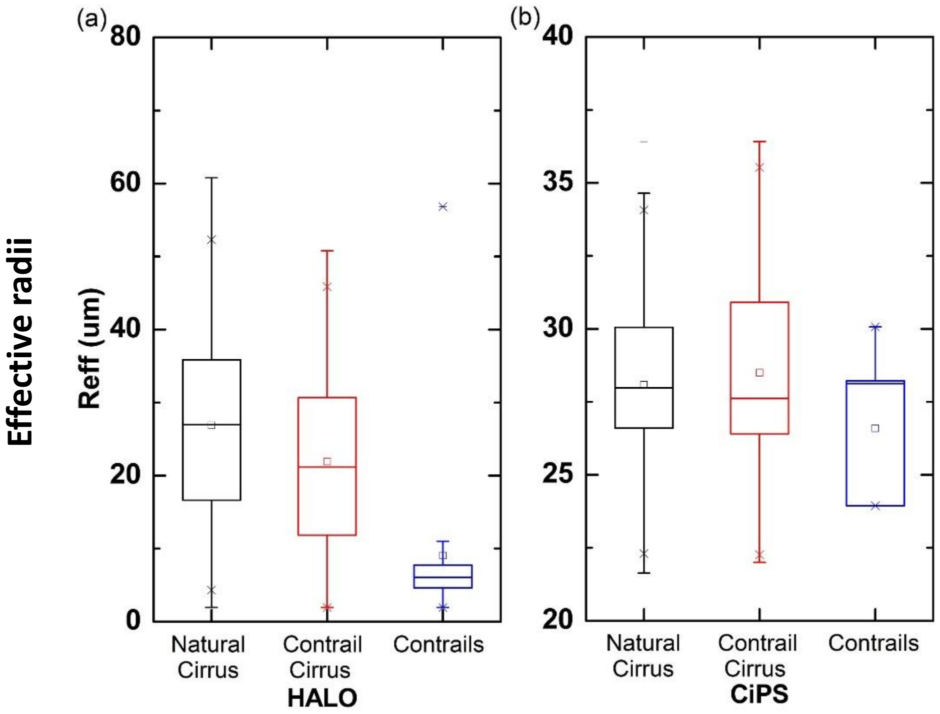

*Fig.3 Reff from **HALO and CiPS** along the HALO flight track*

- AIC and natural cirrus
  - ➢ Smaller Reff from contrail cirrus (HALO)
  - ➢ Satellite observations (CiPS) only show a tendency of smaller Reff for contrails

Estimation of TOA SW radiation using a radiative transfer model

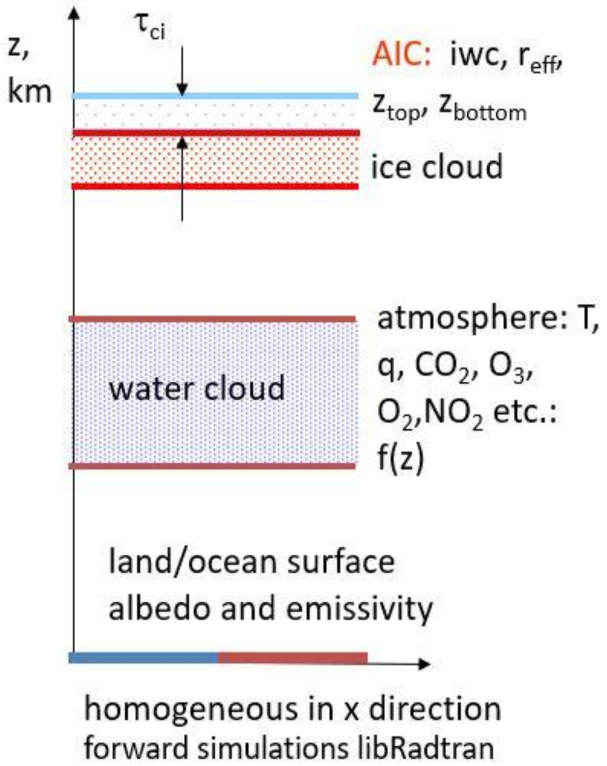

Fig.4 Cloud vertical structure

$$\text{IWC} = \frac{IOT_{CiPS}}{Ext * (CTH - CBH)}$$

(Baum et al. , 2011)

We combine airborne measurements, together with ERA5 natural cloud profiles to calculate TOA RSR and OLR for both cirrus and **cirrus-free regions**

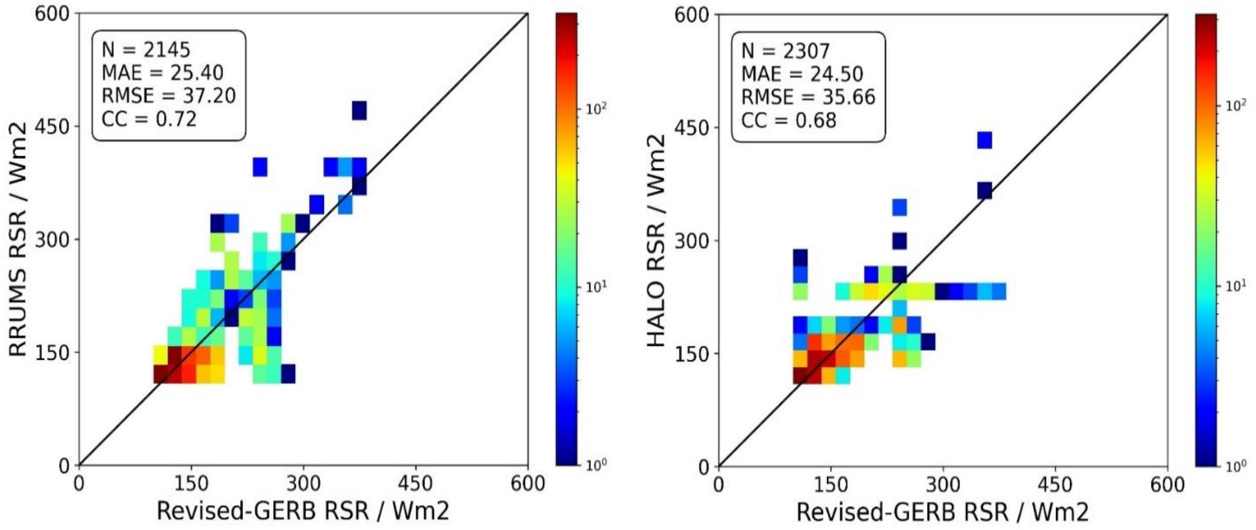

Fig.5 Comparison of TOA RSR from RRUMS results and RTM simulations for probed ice particles against revised-GERB products

RSRs from libRadtran are consistent with RRUMS and GERB, now we can compute RF with libRadtran (RSR/OLR for cirrus and cirrus-free regions)

TOA RF of AIC and natural cirrus

- The TOA RF for AIC and natural cirrus are calculated based on SW and longwave (LW) radiation for both cirrus and **cirrus-free regions using libRadtran**

Table 1. Recorded values for Fig.6

Cirrus/RF(W/m2)	SW	LW	Net
Natural cirrus	-7.0	7.8	0.8
Contrail cirrus	-7.0	8.7	1.7
Contrails	-5.8	6.2	0.4

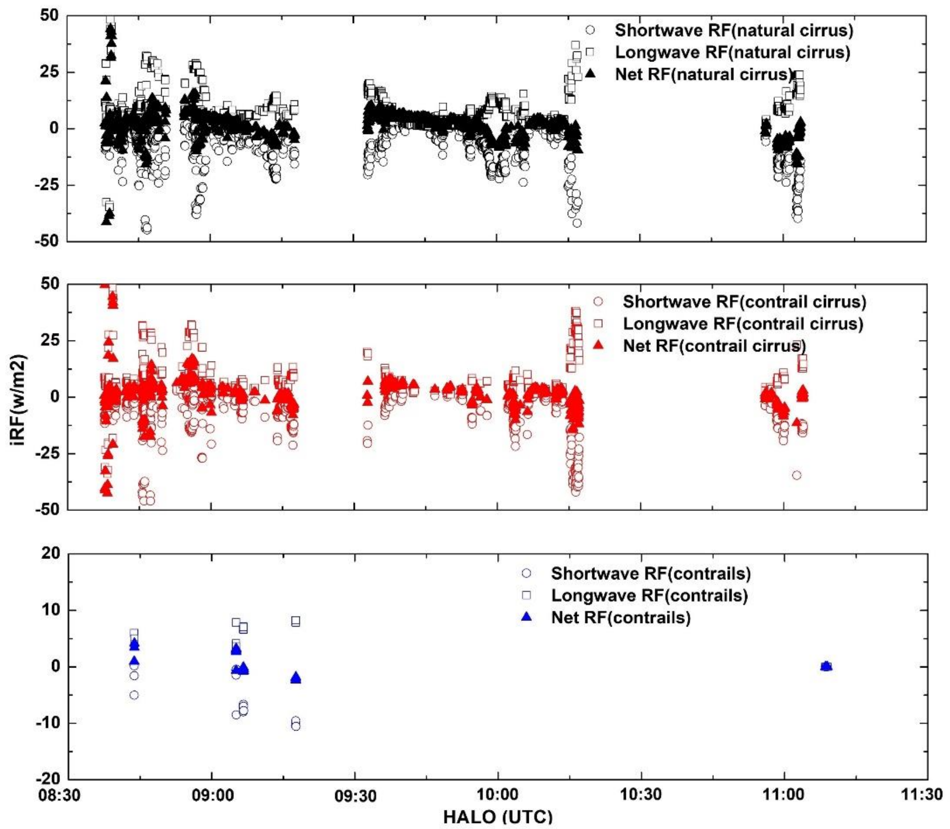

Fig.6 TOA RF for natural cirrus, contrail cirrus and contrails from our RTM simulations for HALO probed ice crystals on 26 March 2014

- ➢ Contrail cirrus RF is usually larger than that of natural cirrus
- ➢ As contrails evolve into contrail cirrus, their net RF shows an increasing trend

Conclusions

- The average **AIC IReff** is about **18% smaller** than natural cirrus. When **contrails envolve**, particle sizes **increase**.
- A TOA RSR and OLR estimation method is developed, **not relying on** observations for radiation for cirrus-free atmospheres
- **AIC net RF** is **averagely warmer** than natural cirrus, which **increases** when **contrails evolve.**

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