



# **Contrail Cirrus Coverage and Radiative Forcing derived from MSG-SEVIRI Data**

H. Mannstein

TAC Conference, Oxford, 2006 - 06 - 28



# Contrail Cirrus:

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Most results are part of the PhD thesis of Waldemar Krebs

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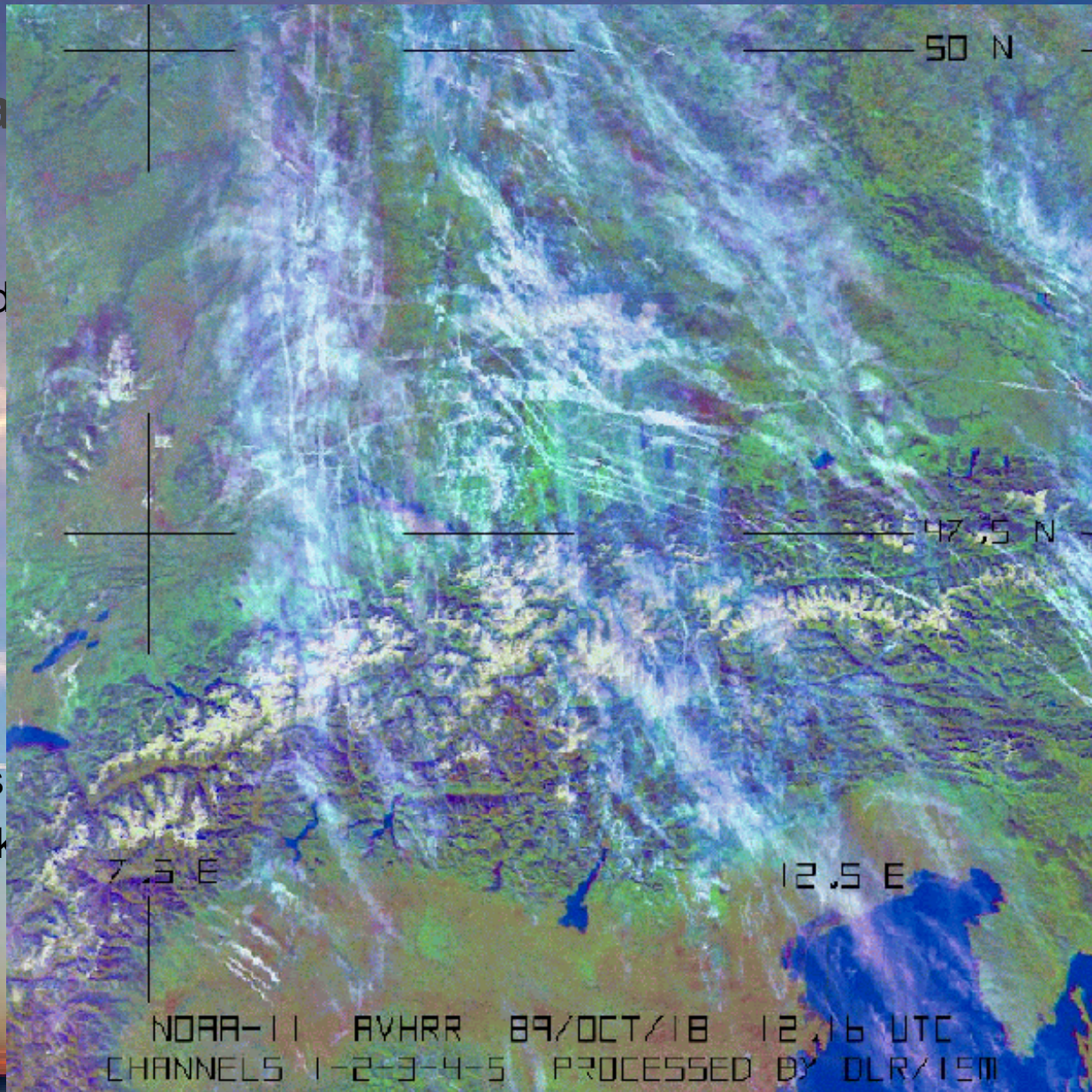


Contra

Wald

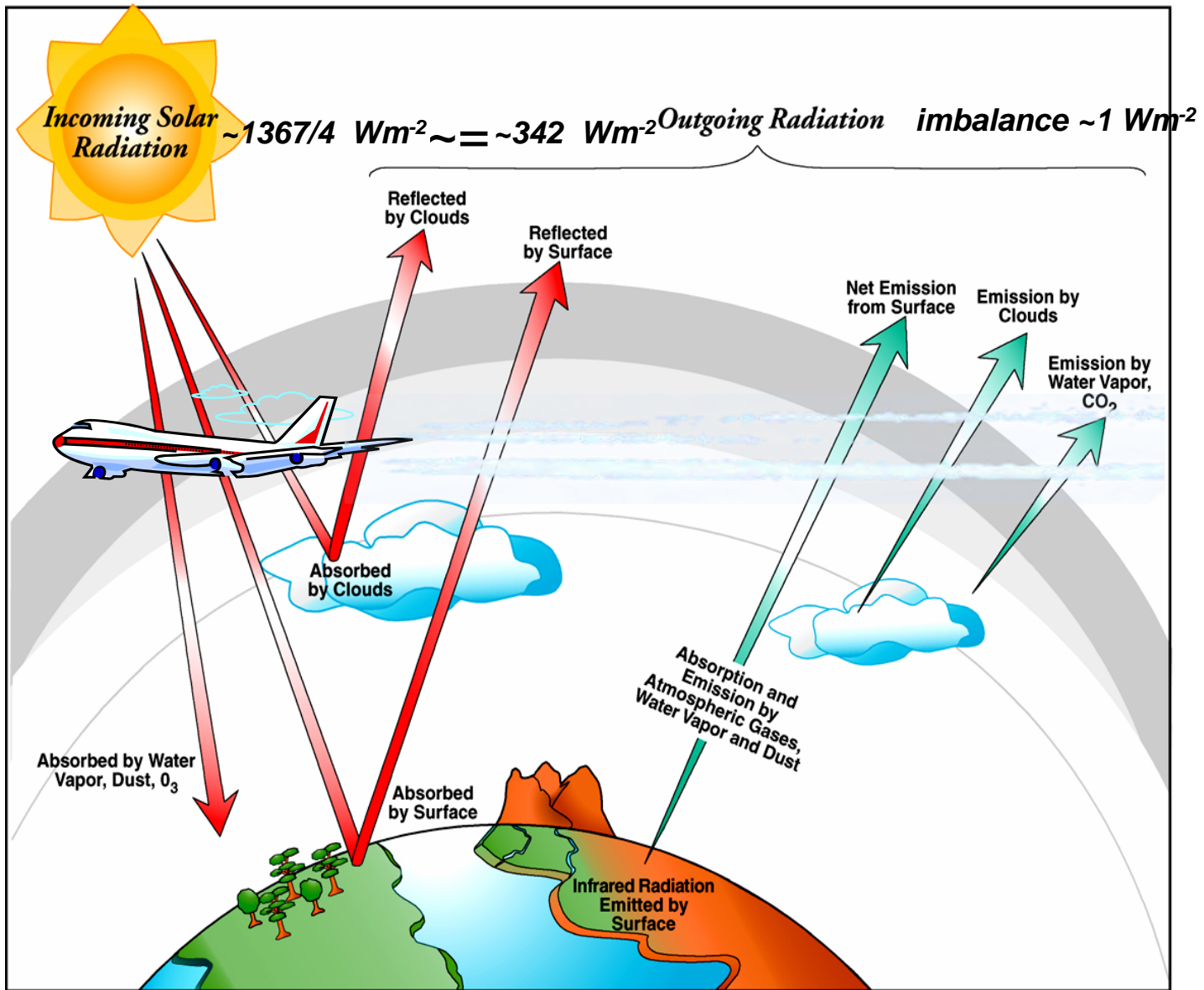
Most res

The work

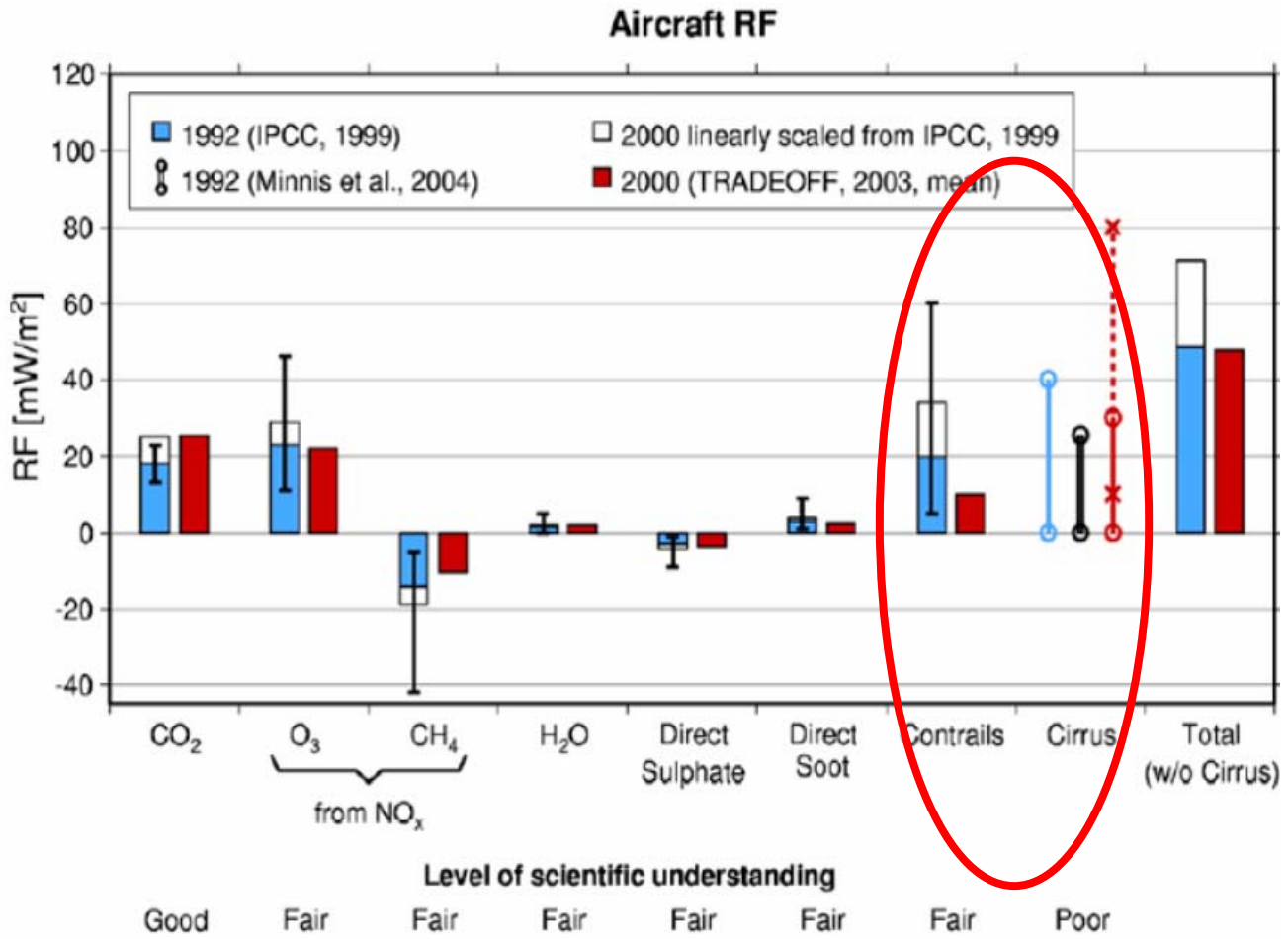


nann

RAILS



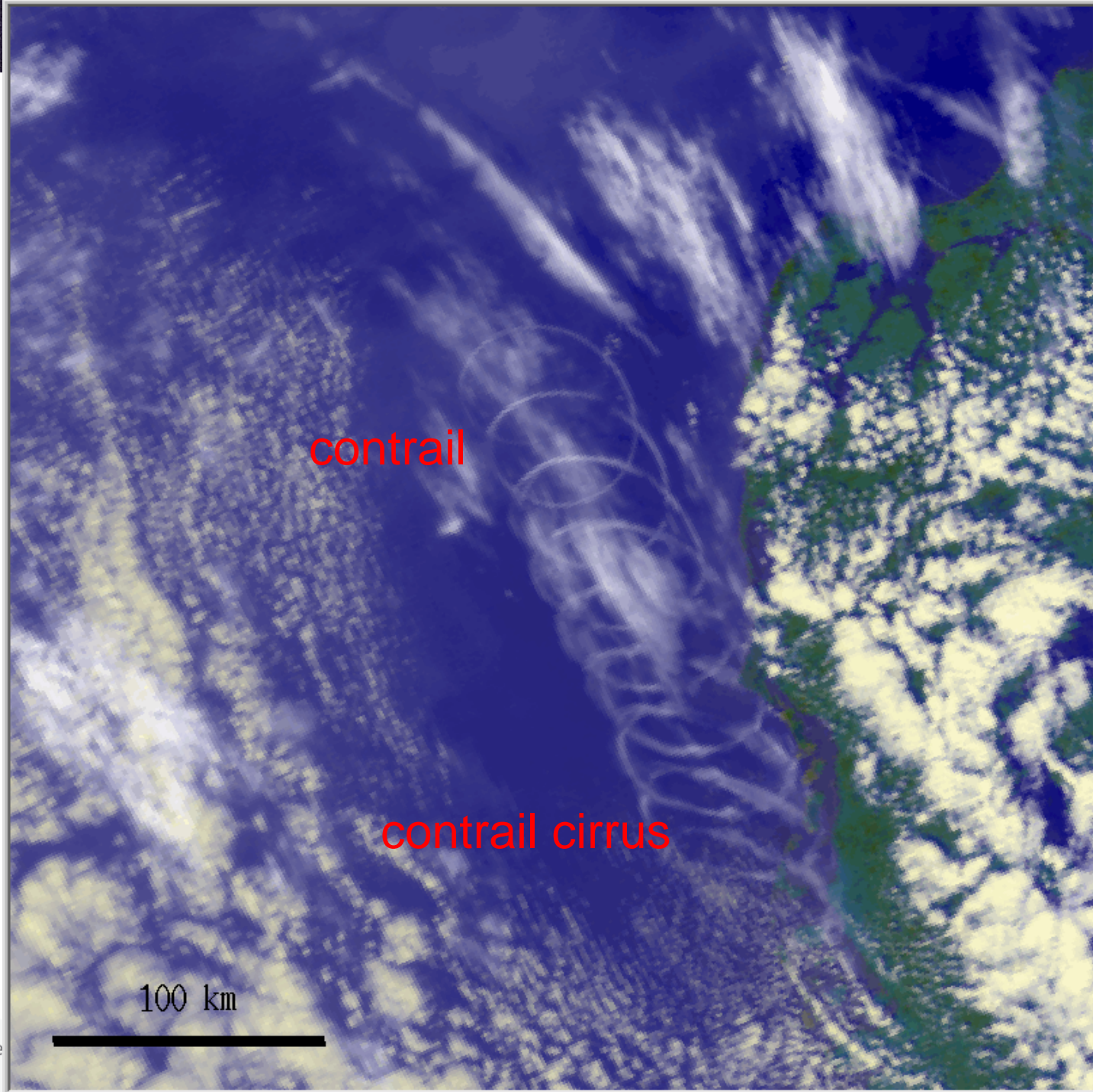




Sausen, Robert; Isaksen, Ivar; Grewe, Volker; Hauglustaine, Didier; Lee, David S.; Myhre, Gunnar; Köhler, Marcus O.; Pitari, Giovanni; Schumann, Ulrich; Stordal, Frode; Zerefos, Christos: **Aviation radiative forcing in 2000: An update on IPCC (1999)** Meteorol. Z. No 14, 4, August 2005, pp. 555-561



- NOAA 14  
AVHRR
- May 22 1998  
12:36
- 'Corkscrew'  
contrail
- ~1600km long,
- ~2.6 h old at the  
end



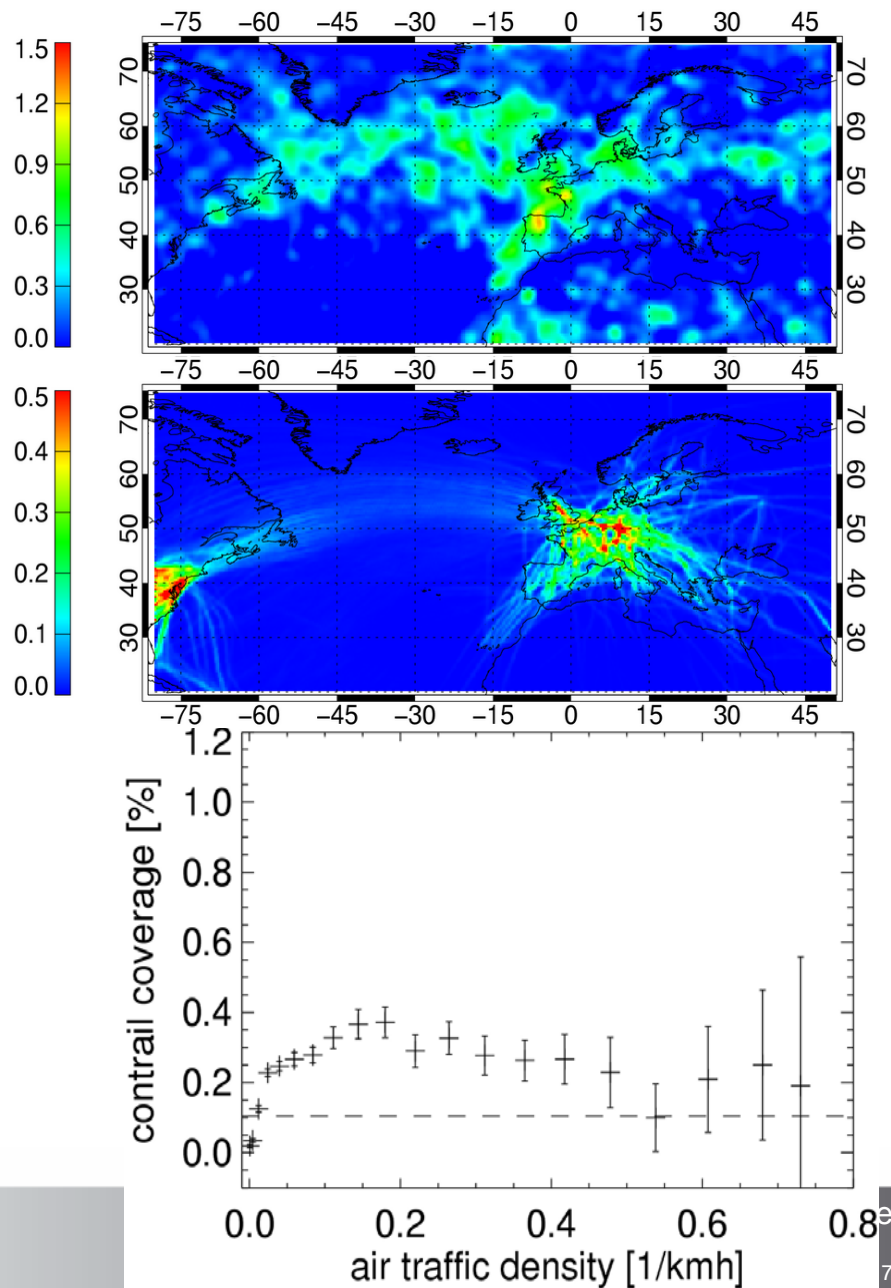


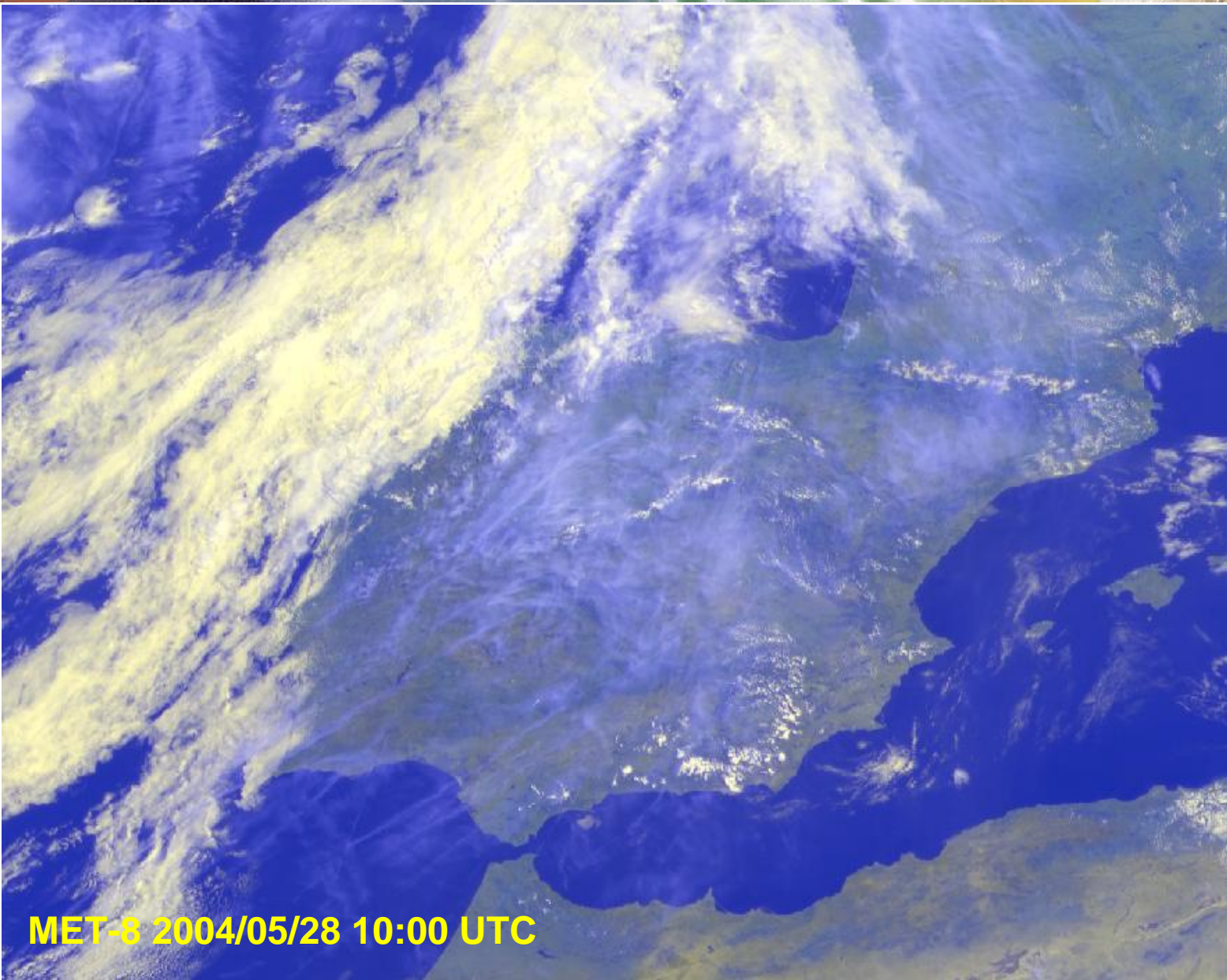
contrail coverage (%) from  
AATSR data 2004  
mean:  $0.11 \pm 0.04\%$

air traffic density  
[km/(km<sup>2</sup>h)] within 1 hour  
before ENVISAT overpass

40% of global air traffic  
11% of global area  
global estimate:

0.03% contrails



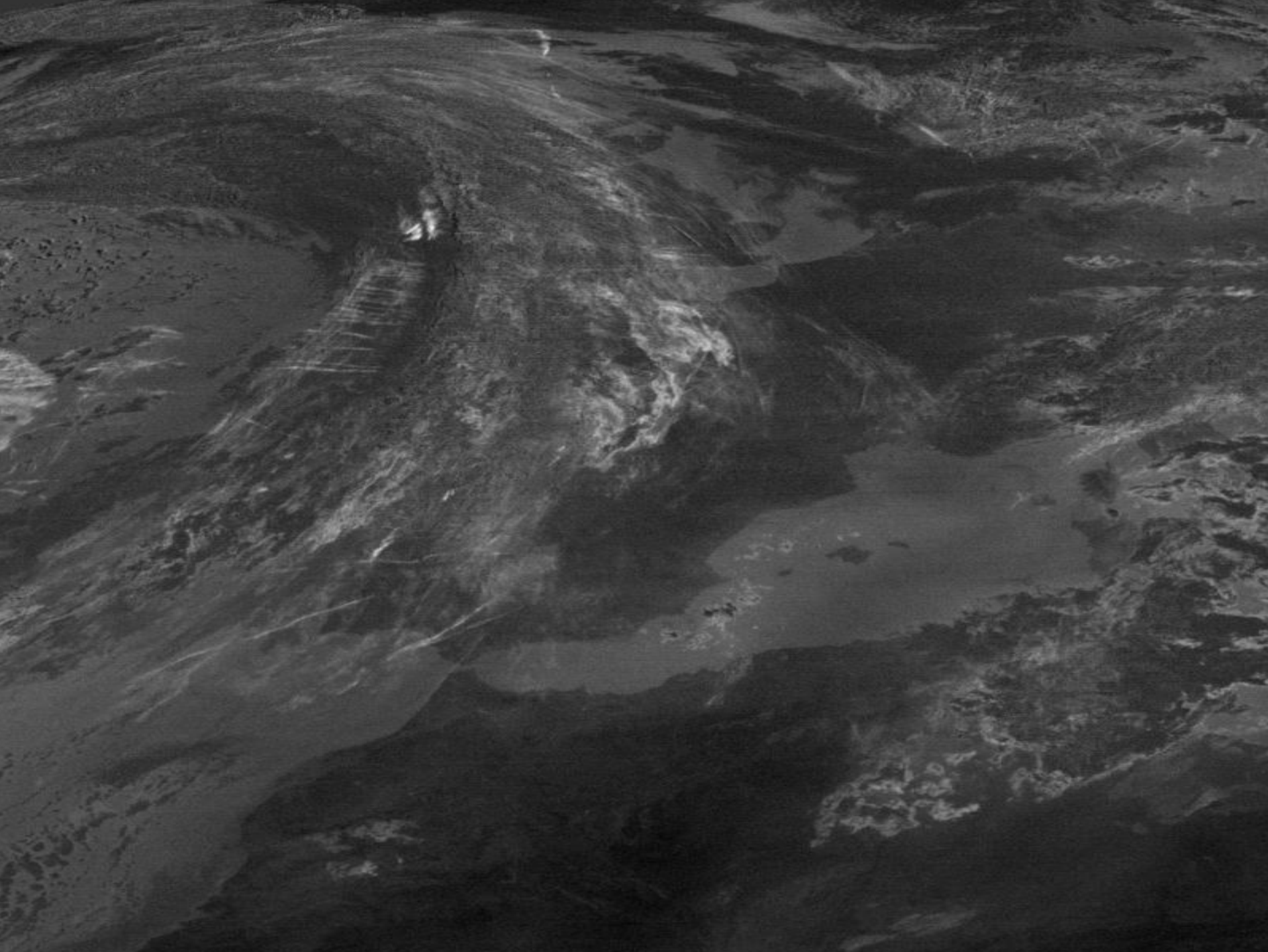


**MET-8 2004/05/28 10:00 UTC**



Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft

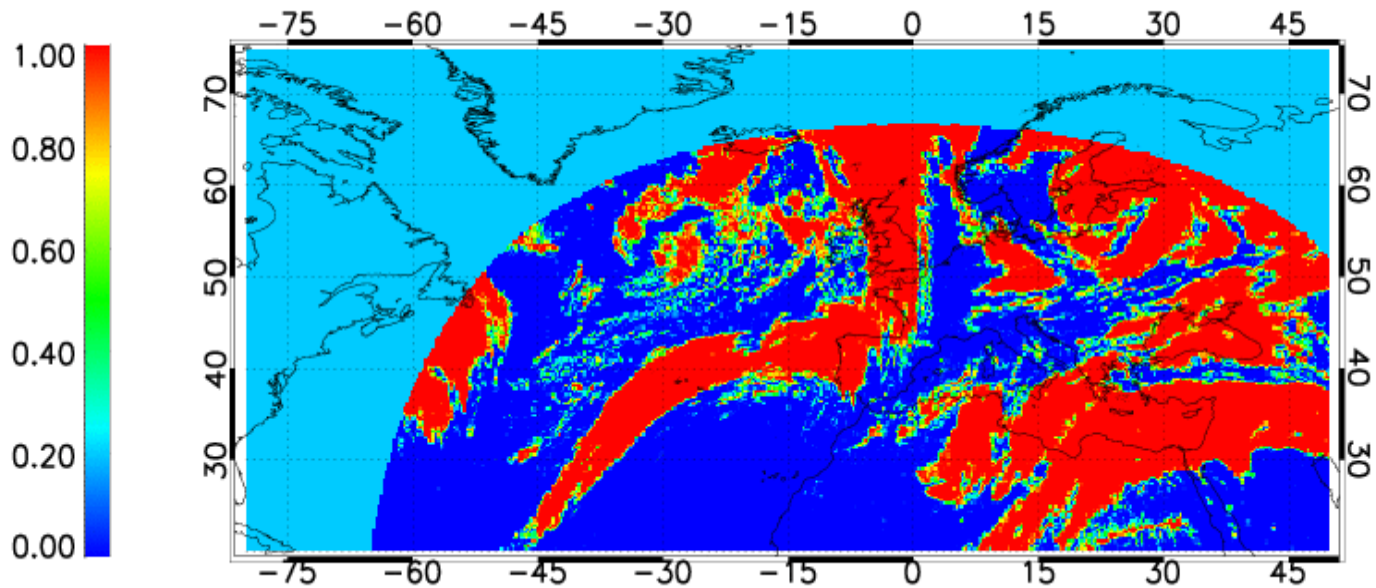
Institut für Physik der Atmosphäre







## Cirrus coverage 0.25° x 0.25° 2004/03/03 00:00

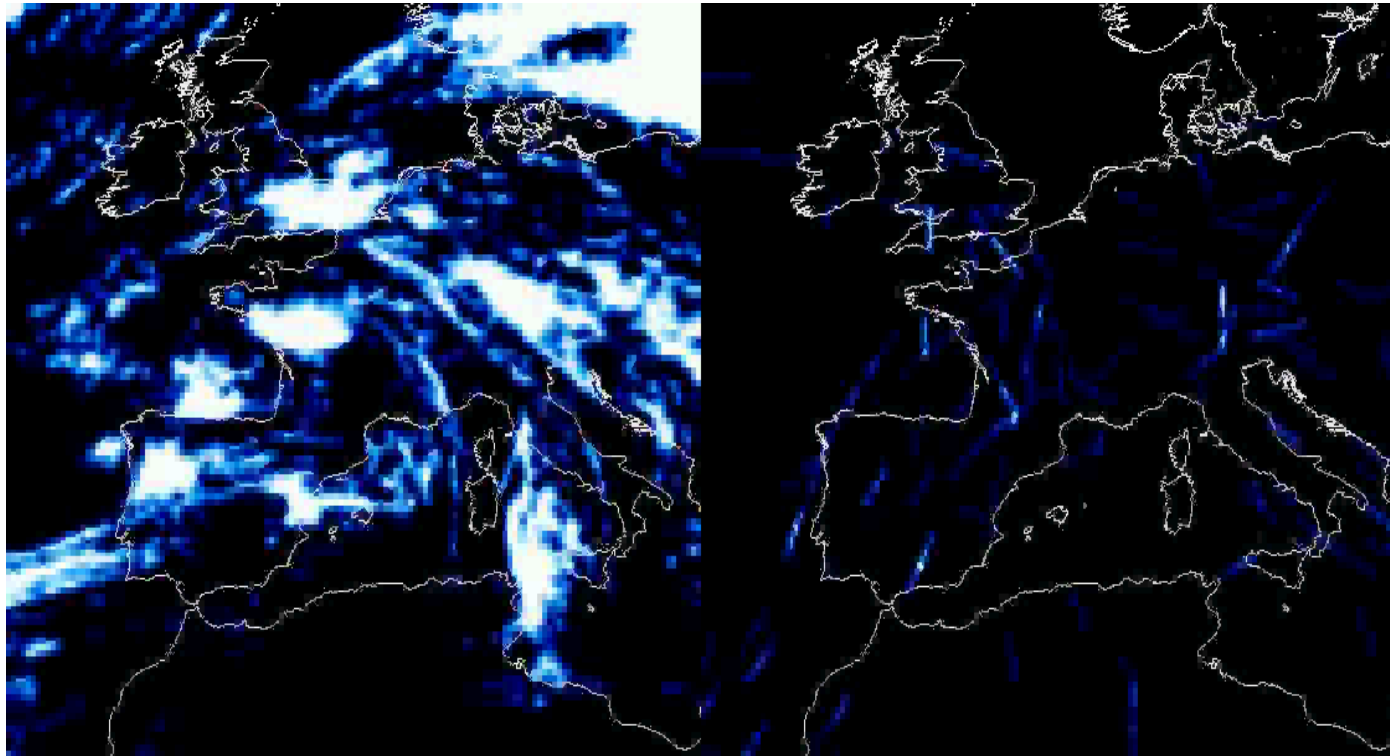




## MSG CIRRUS

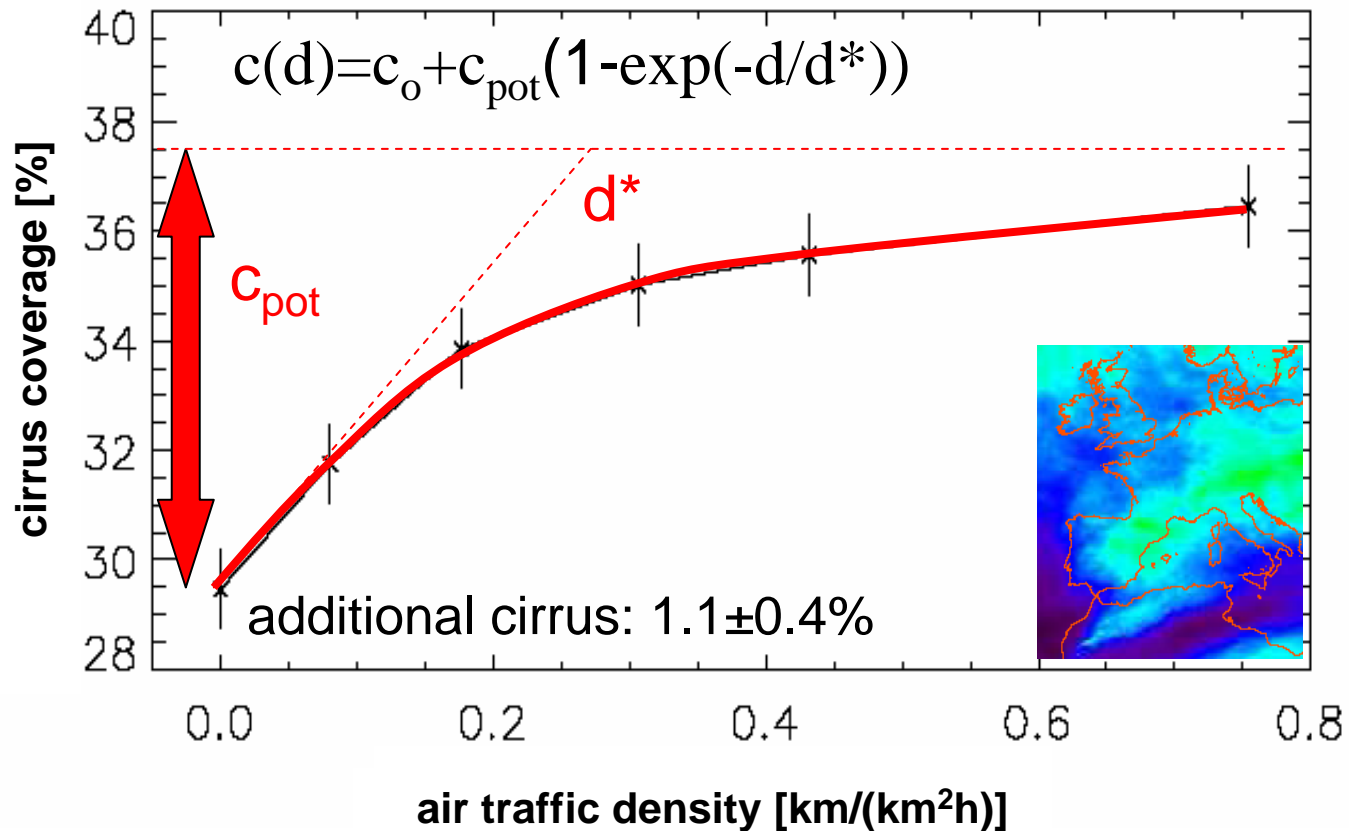
## AIR TRAFFIC DENSITY

flight levels: 200 hfeet - 450 hfeet



equidistant cylindrical co-ordinates, 15W - 20E, 30N - 60N, 0.25° x 0.25°

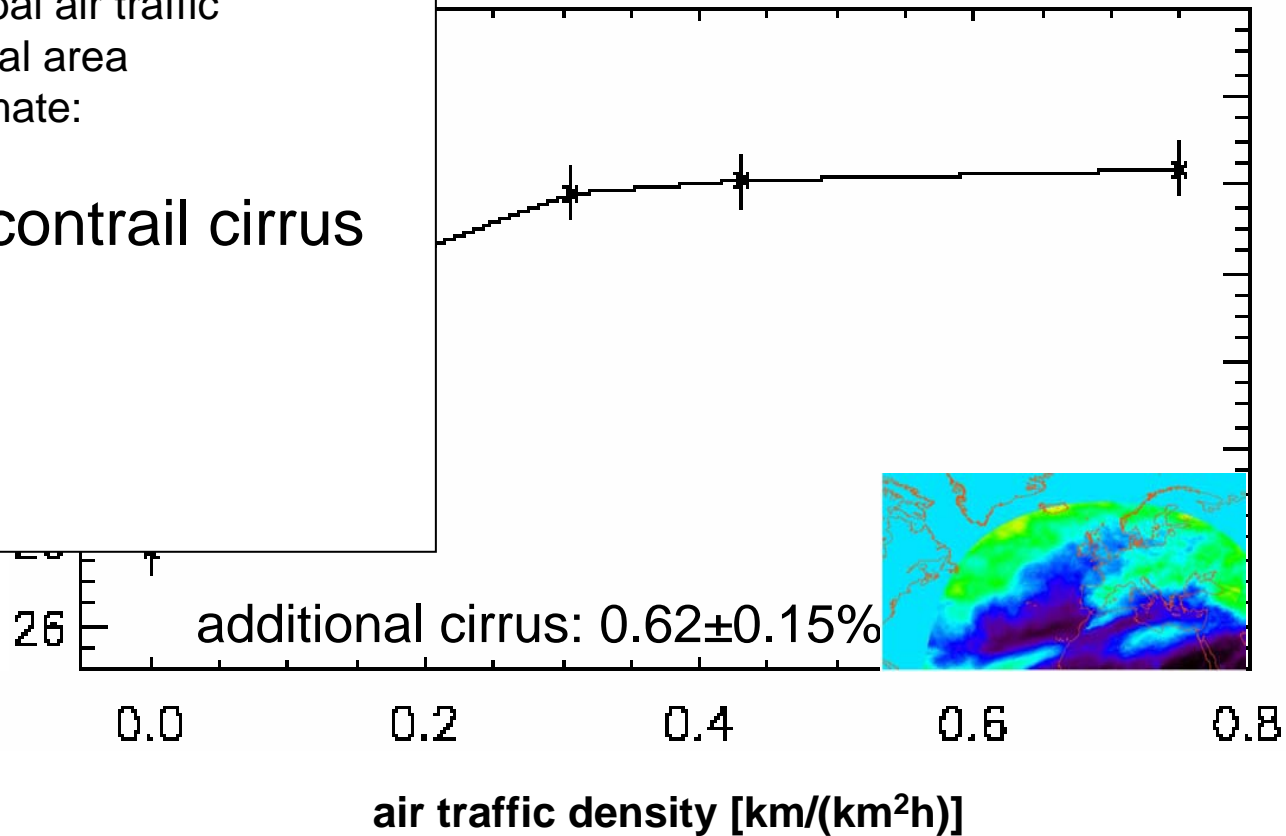
# cirrus coverage vs. air traffic density Feb - Dec 2004



# cirrus coverage vs. air traffic density Feb - Dec 2004

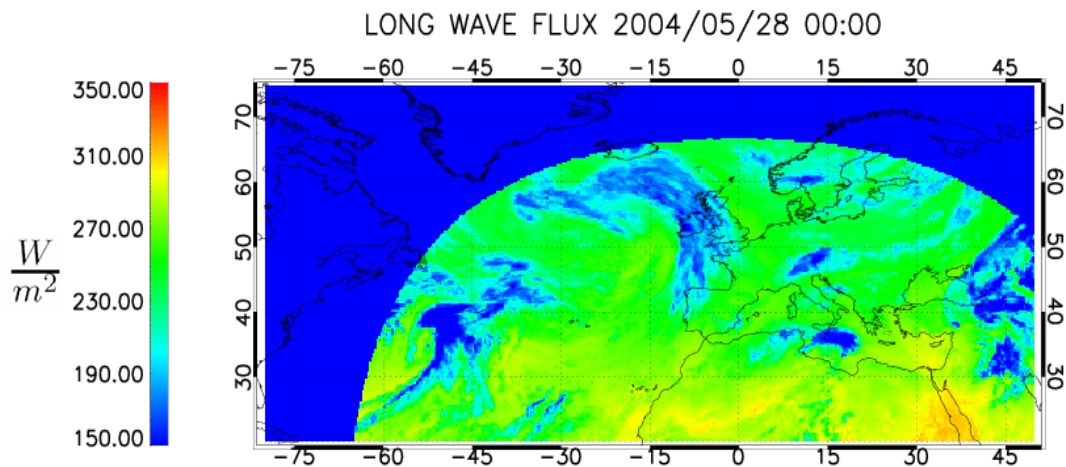
30% of global air traffic  
8% of global area  
global estimate:

0.17% contrail cirrus

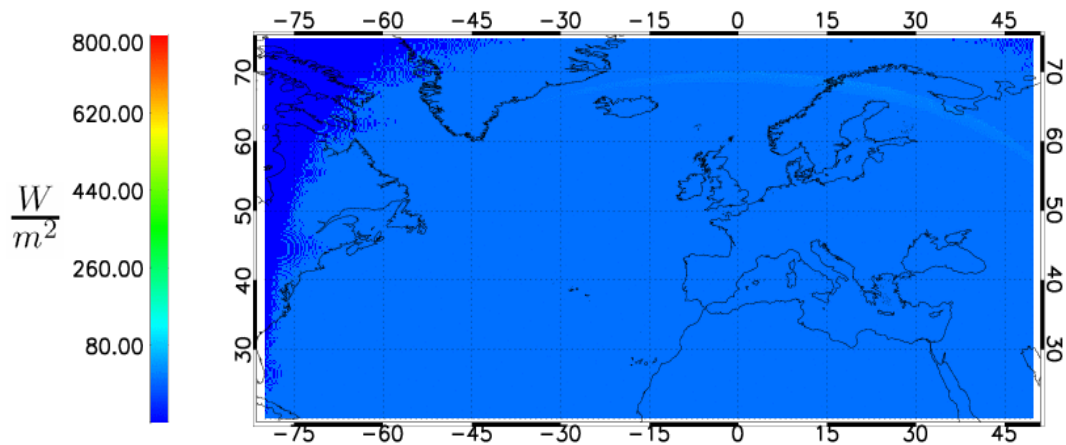




MSG/SEVIRI **terrestrial**  
outgoing flux density  
Top of atmosphere

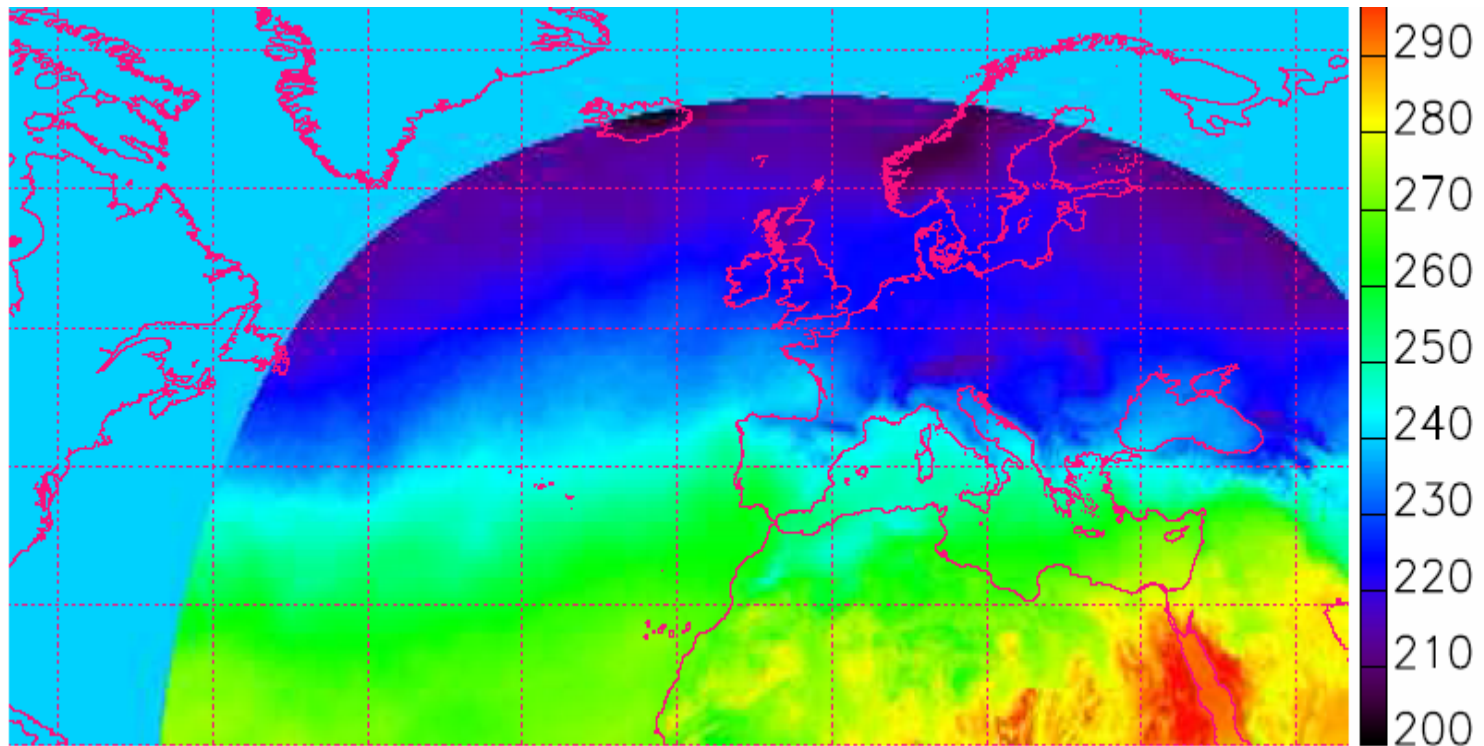


MSG/SEVIRI **reflected**  
outgoing flux density  
Top of atmosphere

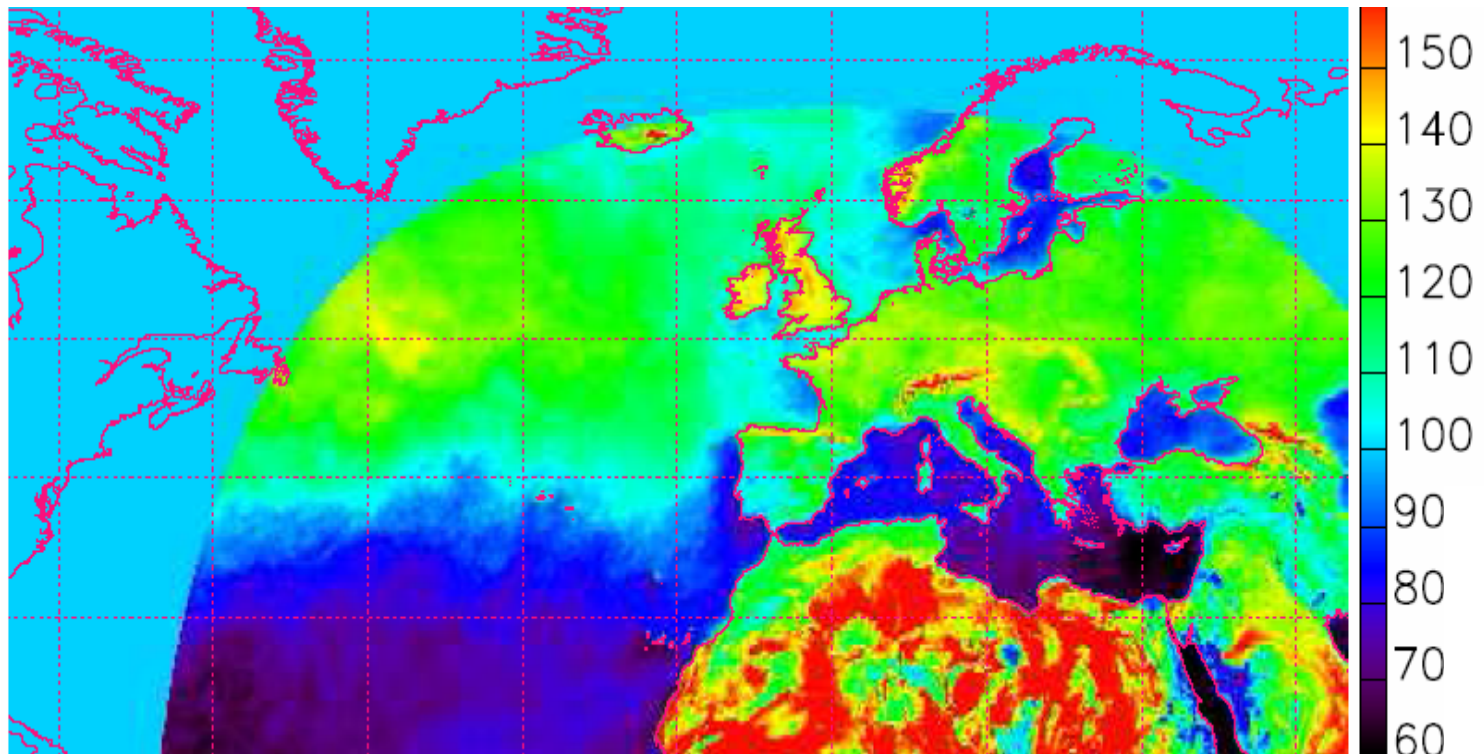




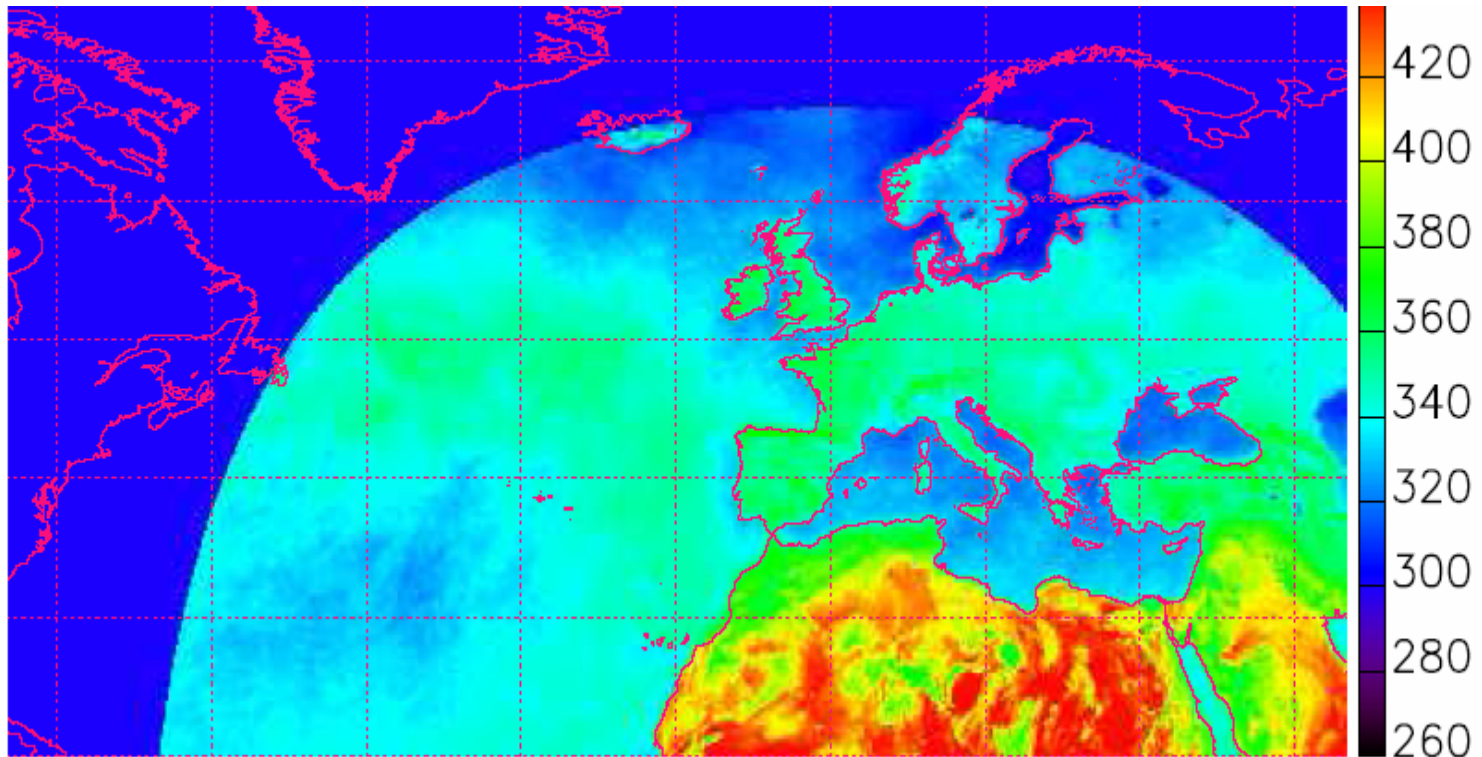
MSG/SEVIRI **terrestrial** outgoing flux density [W/m<sup>2</sup>]  
Top of atmosphere



MSG/SEVIRI **reflected** outgoing flux density [W/m<sup>2</sup>]  
Top of atmosphere



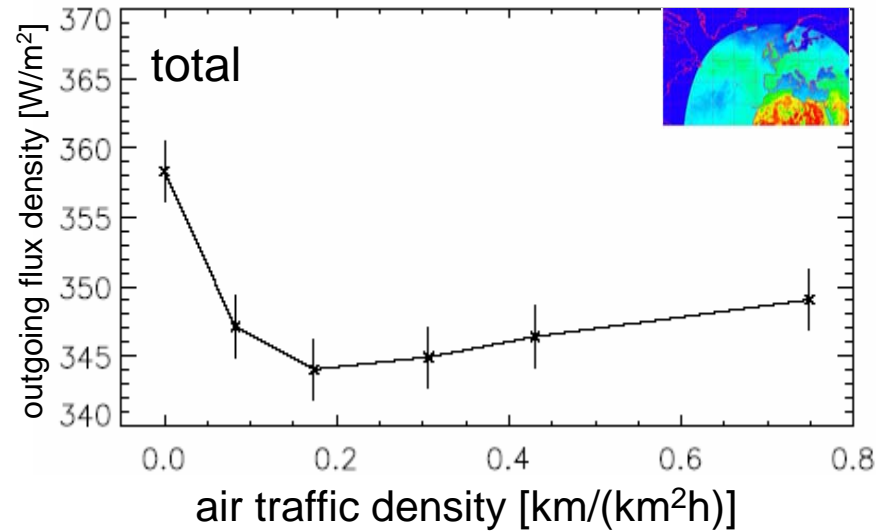
MSG/SEVIRI **total** outgoing flux density [W/m<sup>2</sup>]  
Top of atmosphere



# Outgoing flux density Feb-Dec 2004 vs. air traffic density

difference w/o air traffic

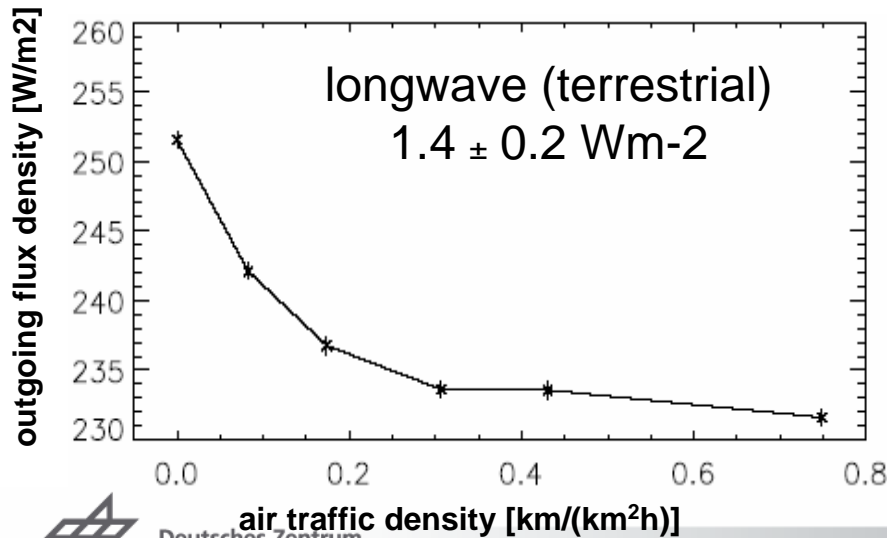
$1.1 \pm 0.8 \text{ Wm}^{-2}$



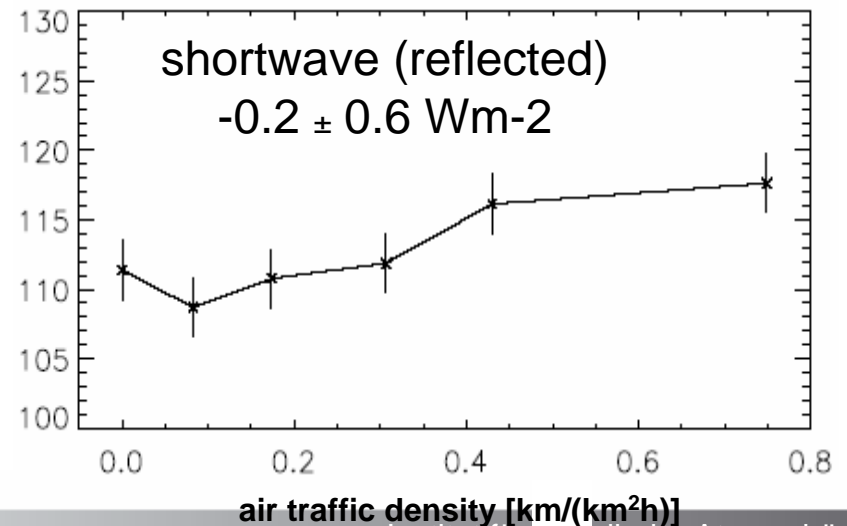
30% of global air traffic  
8% of global area  
global estimate:

$0.3 \pm 0.3 \text{ Wm}^{-2}$

$0.4 \pm 0.1 \text{ Wm}^{-2}$  (LW)  
 $-0.1 \pm 0.3 \text{ Wm}^{-2}$  (SW)



longwave (terrestrial)  
 $1.4 \pm 0.2 \text{ Wm}^{-2}$



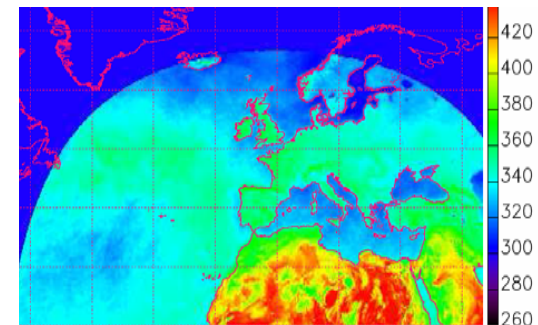
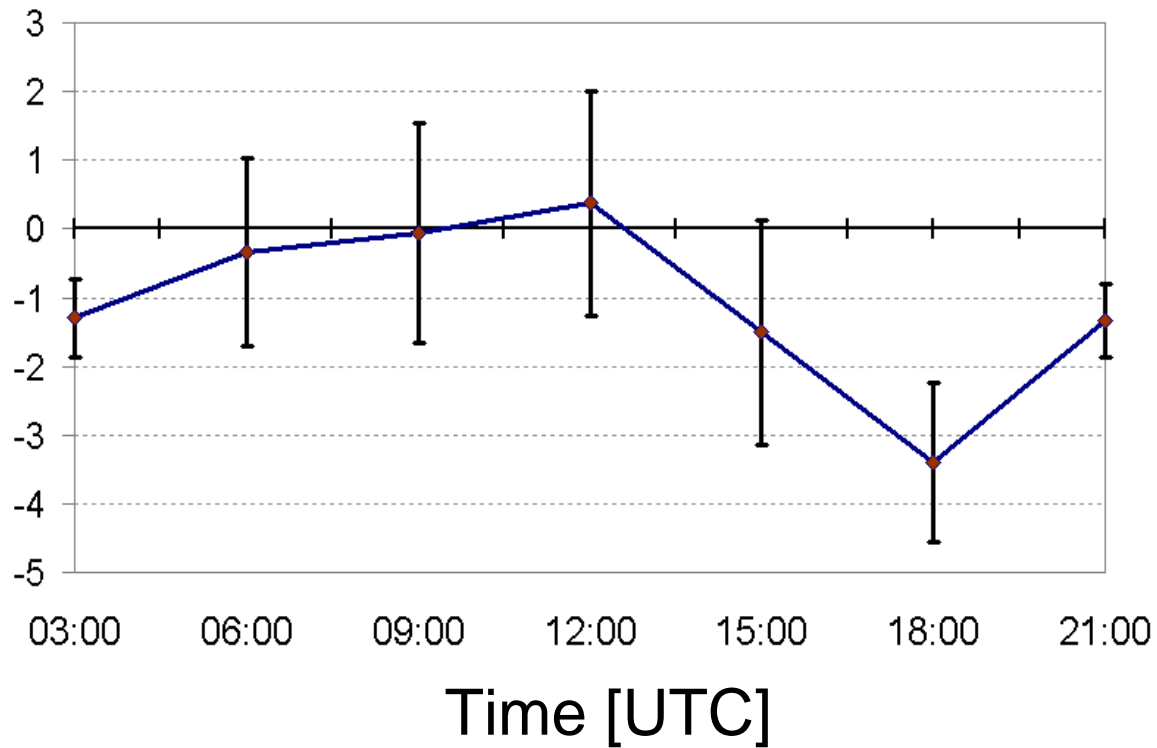
shortwave (reflected)  
 $-0.2 \pm 0.6 \text{ Wm}^{-2}$





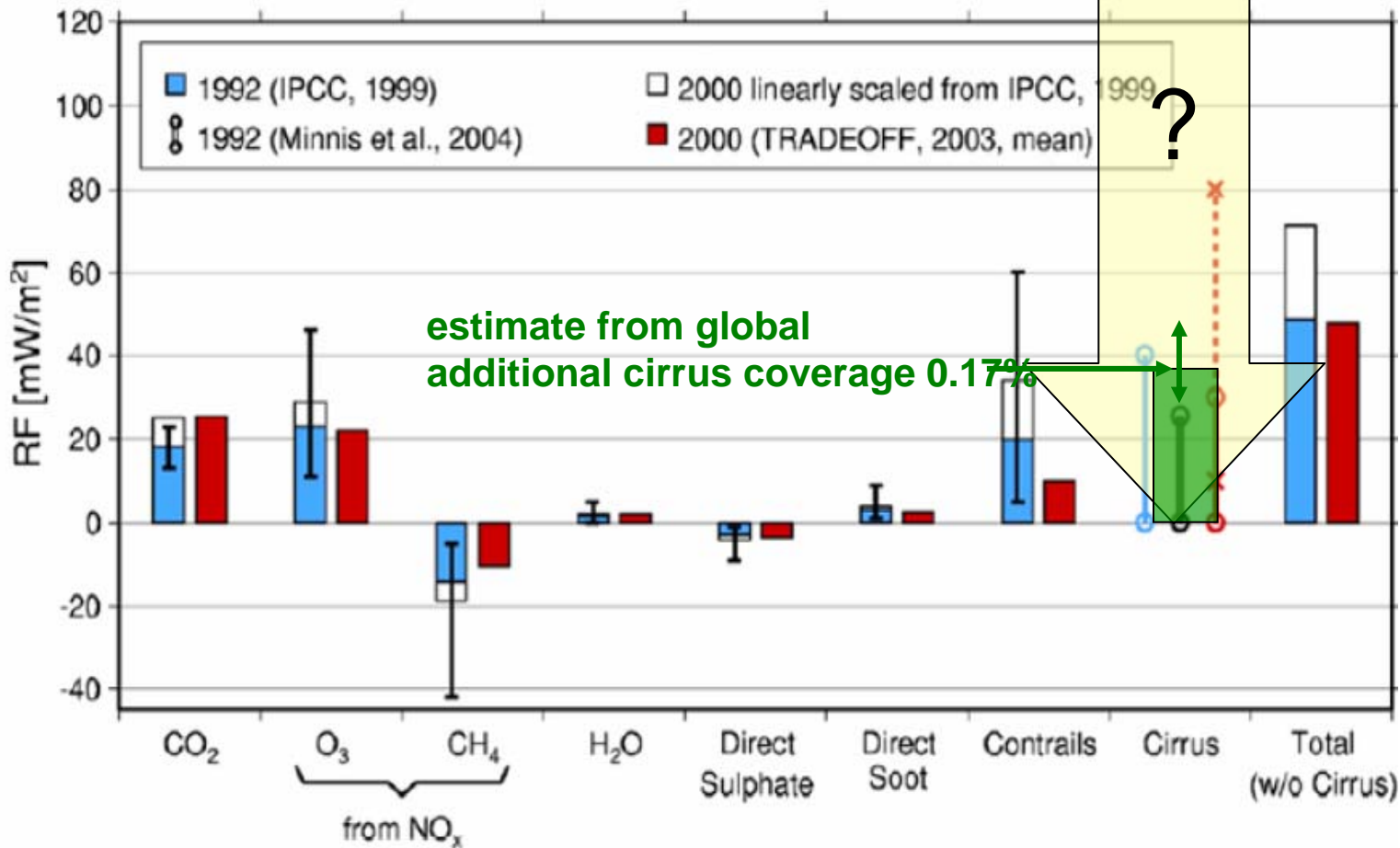


## Diurnal variation: difference outgoing radiation [ $\text{W}/\text{m}^2$ ]





### Aircraft RF



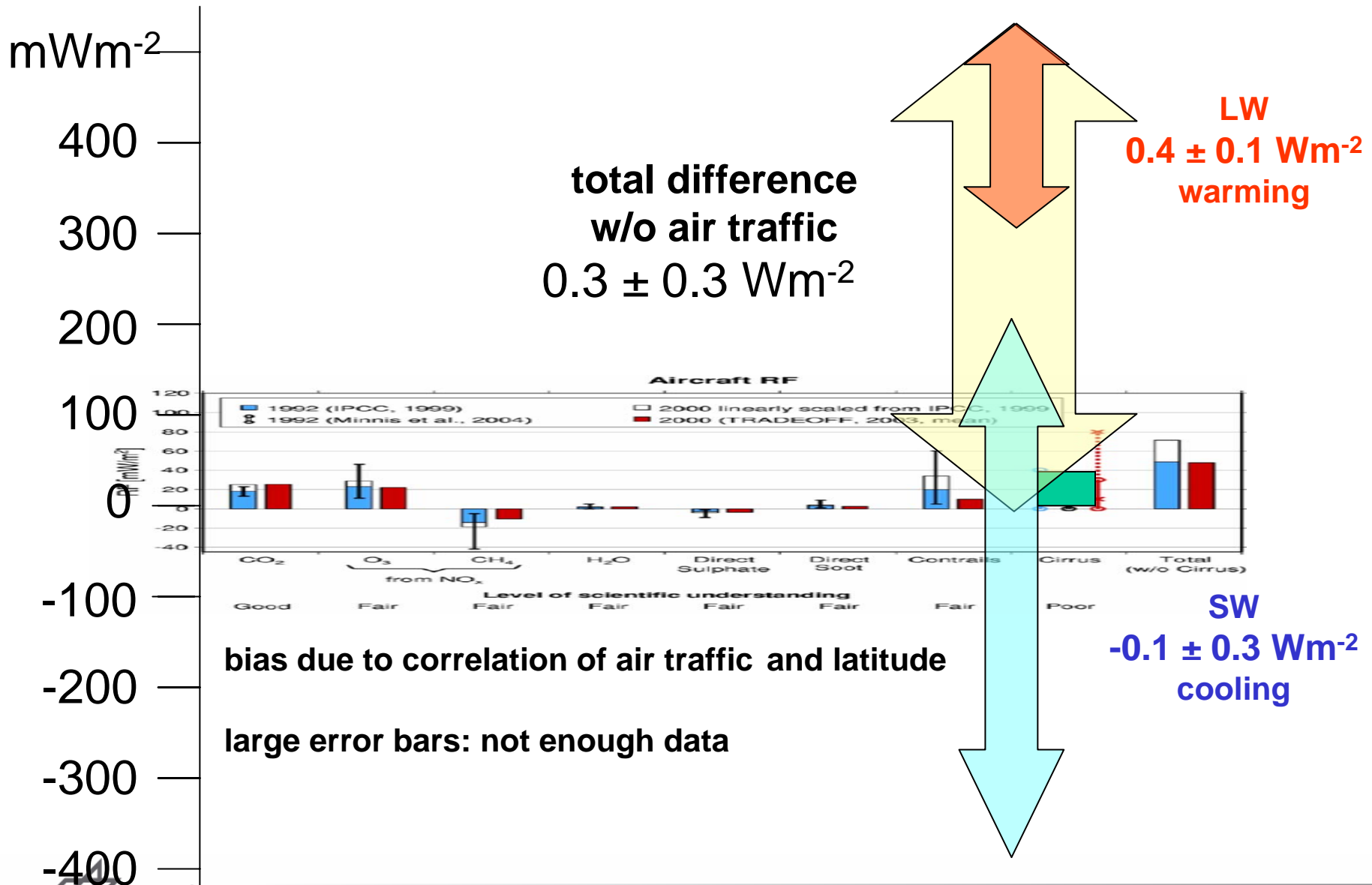
$0.3 \pm 0.3$   
Wm<sup>-2</sup>

?

estimate from global additional cirrus coverage 0.17%

Level of scientific understanding

Good Fair Fair Fair Fair Fair Fair Poor

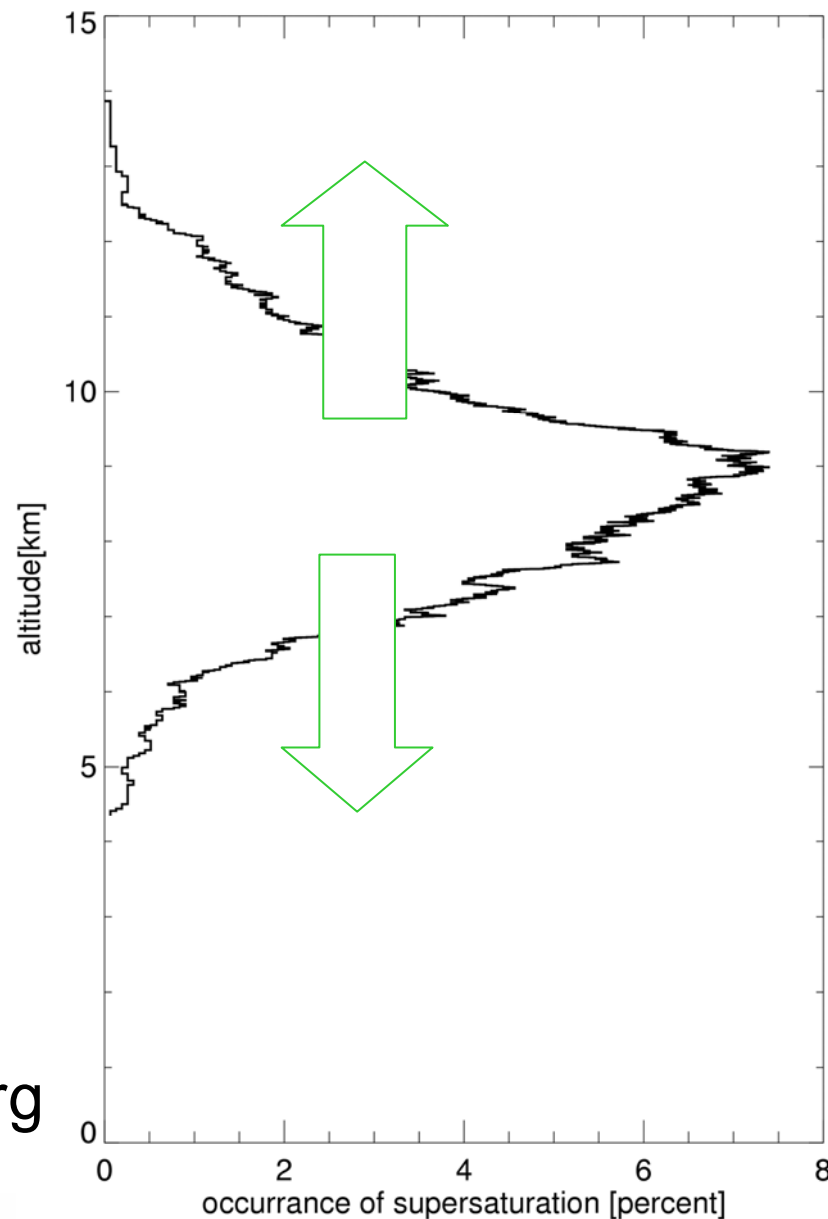




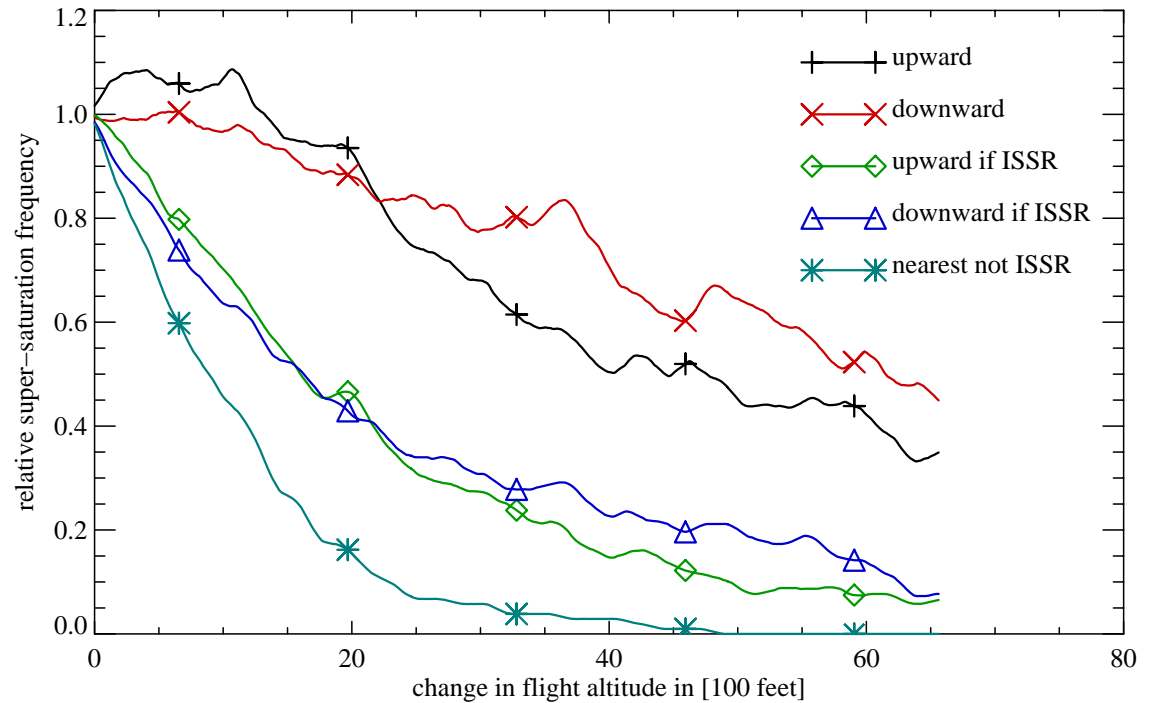
**Option 1: 'Flying higher'**

**Option 2: 'Flying lower'**

Ice supersaturated regions (ISSRs)  
from  
1556 radiosoundings over Lindenberg



## Option 3: 'Flying smarter'



**+ concentrate on the warming contrail cirrus**



# CU you at the poster

## How to avoid contrail cirrus

Hermann Mannstein, Klaus Gierens,  
Waldemar Krebs, Peter Spichtinger<sup>1</sup>

Institut  
für  
Physik der  
Atmosphäre



### Introduction

The impact of aviation on climate follows several pathways. Carbon dioxide and water vapour, both effective greenhouse gases, are emitted as well as nitric oxides, which influence the chemical composition of the upper troposphere. Soot and sulphuric oxides add to the ambient aerosol and have an impact on cirrus formation and cloud microphysical properties. Since the IPCC special report on "Aviation and the Global Atmosphere" (1999) it is known and widely accepted that contrails and the cirrus clouds evolving out of them have a climate impact comparable to the CO<sub>2</sub> from the combustion process. These additional, purely man-made clouds change the radiative forcing of the earth-atmosphere system: they reduce the incoming solar radiation as well as the outgoing thermal radiation.

### Option 1: "Flying lower"

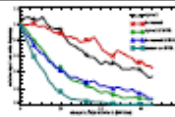
### Option 2: "Flying higher"

The vertical distribution of ice super-saturated regions (SSR) shows a maximum close to the tropopause. Here we analysed 1576 radiosoundings over Leidenburg, Germany from February 2000 to April 2001. The altitude of the climatological maximum changes with season and latitude. Avoiding the maximum will obviously reduce the occurrence of persistent contrails.

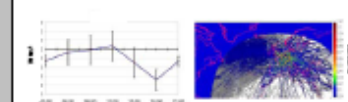


### Option 3: "Flying east"

Using the same radiosonde data we calculated the relative frequency to find an SSR after a change in flight altitude for different strategies. The red line refers to "flying lower", the black one to "flying higher". In both cases the altitude has to be changed by more than 6000 feet in order to reach a reduction of contrail formation by 50%. The same reduction is reached by a change of less than 2000 feet with a smart strategy: only if an SSR is encountered, it is left (green -> upward; blue -> downward). If the direction to the nearest not super-saturated level is known, a change by 1000 feet is sufficient to avoid half of the contrails.

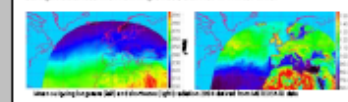


### Additional considerations: time and season



Self radiation of the contrails in the night-time is a significant effect to be taken into account. The self radiation of the contrails in the night-time is a significant effect to be taken into account.

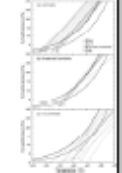
During daytime the warming due to the reduced outgoing longwave radiation is balanced by the enhanced reflection of solar radiation. The total effect of contrail cirrus is dominated by the night-time traffic. The same argument is valid for the seasonal dependency: in summer the reflected sunlight balances the warming effect, but not in winter time.



**No option:** old, less efficient engines (D17, right) release more heat together with the exhaust gases than modern ones (A380, left). Thus the formation of contrails is suppressed under certain ambient conditions.

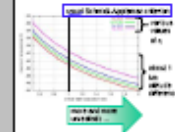
### Contrail formation

The Schmidt-Appleman criteria describe the ambient conditions necessary for contrail formation: During the mixing process of the hot and moist exhaust gases with the ambient air (indicated by the lines in the figure on the left) saturation with respect to liquid water (dotted line) has to be reached. Contrails in dry air (below the dashed line of saturation with respect to ice) evaporate quite soon. Only in ice-super-saturated engine persistent contrails will form.



### Are fuel additives a viable contrail mitigation option?

Fuel additives have been proposed as a potential mitigation option for contrails. They could change the Schmidt-Appleman criteria in a way that makes contrail formation more difficult than with standard kerosene fuel. The figure shows how additives could affect the Schmidt-Appleman criteria. We conclude that fuel additives are not a useful way to avoid contrails.



### Strategy: Avoid the warming contrail cirrus

- at night time
- during daytime over bright surfaces (low clouds, desert)

### Necessary development - Meteorology

- better representation of upper tropospheric humidity in now- and forecast models
- better and more measurements of humidity (aircraft, ozonesonde, lidar) from space, contrails as proxy
- prediction of the potential RF as additional input for an optimized routing

### Necessary development - ATM

- more flexibility in routing -> better optimization
- flexible free flight
- information on the potential RF is the cockpit

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