How to avoid contrail cirrus

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Introduction

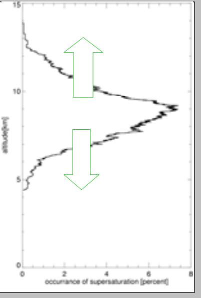
The impact of aviation on climate follows several pathways. Carbon dioxide and water vapour, both effective greenhouse gases, are emitted as well as nitric oxides, which influences the chemical composition of the upper troposphere. Soot and sulphuric oxides add to the ambient aerosol and have an impact 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 CO2 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.

No option: old, less efficient engines (B707, right) release more heat together with the exhaust gases then modern ones (A340, left). Thus the formation of contrails is supressed under certain ambient conditions

Option 1: 'Flying lower'

Option 2: 'Flying higher'

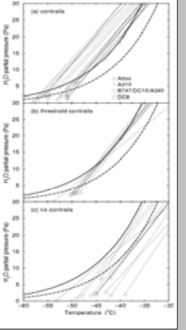
The vertical distribution of ice supersaturated regions (ISSRs) shows a maximum close to the tropopause. Here we analysed 1556 radiosoundings over Lindenberg, Germany from February 2000 to April 2001. The altitude of the climatological maximum changes with season and latitude. Avoiding the maximum will obviously reduce the occurrance of persitent contrails.



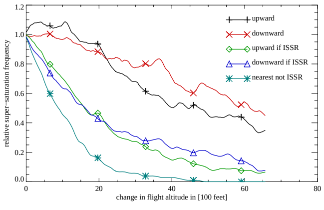
Contrail formation

The Schmidt-Appleman criterion describes 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 (full 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-supersaturated regions persistent contrails will form.

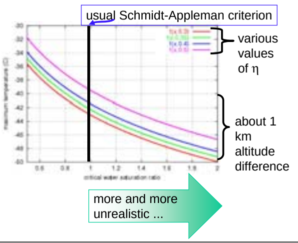


Option 3: 'Flying smart'



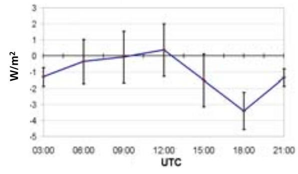
Using the same radiosonde data we calculated the relative frequency to find an ISSR after a change in flight altitude for different strategies. The red line refers to 'flying lower', the black one to 'flying higher'. In both cases the altitude has to be changed by more then 6000 feet in order to reach 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 ISSR is encountered, it is left (green - upward, blue downward). If the direction to the nearest not saturated level is known, a change by 1000 feet is sufficient to avoid half of the contrails.

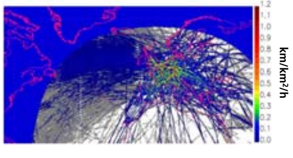
Are fuel additives a viable contrail mitigation option?



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

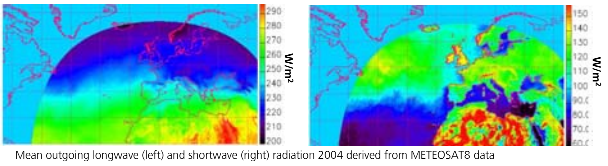
Additional considerations: time and season





Daily variation of the radiative forcing of air traffic 2004 derived from METEOSAT8 data for the region indicated in the right image showing the mean air traffic density in the area seen by the satellite. The values result from the statistical analysis of outgoing radiation in combination with air traffic data in 1/4 h resolution.

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.



Mean outgoing longwave (left) and shortwave (right) radiation 2004 derived from METEOSAT8 data

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, radiosonde, 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 in the cockpit

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