Impacts of aircraft-induced black carbon on cirrus clouds: Simulations with the ECHAM4-GCM

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Introduction

Global simulations on the potential impact of aircraft-generated black carbon (BC) particles on cirrus clouds via heterogeneous ice nucleation were performed. The general circulation model ECHAM4 has been extended by an aerosol module and a microphysical cloud scheme (Figure 1). The global impact of aircraft BC emissions on the concentration of potential heterogeneous ice nuclei (IN) in the upper troposphere and lowermost stratosphere (UTLS) was quantified (Figures 2, 3). Potential impacts of BC from aircraft on cirrus clouds were simulated. Sensitivity experiments were performed considering various scenarios of ice nucleating efficiencies of different types of potential IN (Figure 4).

The model system

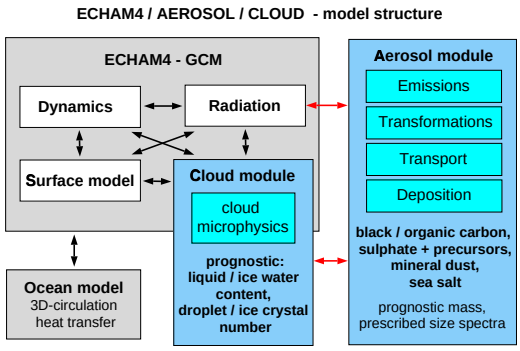

Figure 1: Model structure.

Impacts of aviation BC emissions on cirrus

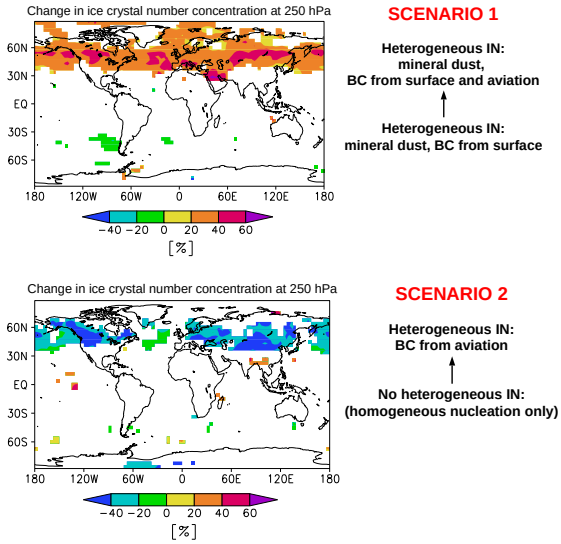

Figure 4: Maximum estimated relative changes of the annual mean ice crystal number concentration at 250 hPa (within main aircraft flight levels) induced by heterogeneous ice nucleation on BC particles from aviation; 95% significance level of the student t-test; 10-year averages. Either heterogeneous or homogeneous ice nucleation is considered, dependent on N(het. IN) [N_{crit}=0.5 cm^{-3}].

Heterogeneous IN in the UTLS

N(BC)+N(mineral dust), from surface soures , 250hPa

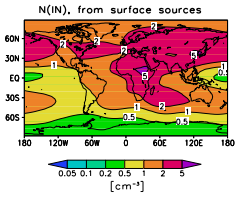

Figure 2: Annual mean number concentration [particles/cm^3] of potential heterogeneous IN (BC and mineral dust particles) at 250 hPa (within main aircraft flight levels); 10-year averages. Only particles originating from surface sources are considered.

Impact of BC from aviation on IN number at 250hPa

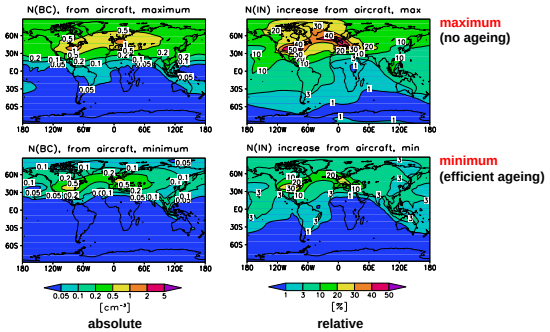

Figure 3: As Figure 2, but for BC particles from aircraft. Maximum and minimum estimates of the absolute and relative aviation impact on N(BC)+N(mineral dust).

Conclusions

- The simulated large-scale impact of aviation BC emissions on the UTLS BC mass concentration is small (not shown).
- The simulations suggest a significant aviation impact on the number concentrations of UTLS BC particles and potential heterogeneous IN. Large-scale increases of the potential heterogeneous IN number concentration of up to 50% are simulated (Figures 2, 3).
- Provided that BC particles from aviation serve as efficient heterogeneous IN, maximum increases or decreases in ice crystal number concentrations of more than 40% were simulated assuming that 'background' (no aviation impact) cirrus cloud formation is dominated by heterogeneous or homogeneous nucleation, respectively (Figure 4).
- Future model studies should consider i) more detailed parameterizations of ice nucleation mechanisms and subscale vertical fluxes; ii) aerosol impacts on subscale ice cloud coverage; iii) dispersion of contrails to cirrus; iv) results of current laboratory and field studies on heterogeneous ice nucleation.

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