Airborne Contrail Ice Measurements from Biofuels

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Keywords: aviation climate impact, contrail measurements, soot activation, biofuels.
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At present, contrails and contrail cirrus contribute the largest single component to the climate impact from aviation, even surpassing the radiative forcing from its CO_2 emissions. One way to mitigate the warming by contrail cirrus might be the reduction of initial ice number concentrations in contrails, for example with the use of sustainable alternative jet fuels. In this context, observations of the relation between particle emissions from the aircraft's engine and ice crystals nucleating in contrails are needed.

To investigate aviation emissions and contrail formation, the **ECLIF II/NDMAX** experiment took place over northern Germany in January 2018. During the aircraft campaign, the NASA DC-8 chased the DLR A320 ATRA, which was fuelled with biofuel blends with varying aromatic contents. The reference fuel Jet A1 was blended with the biofuel HEFA (hydro-processed esters and fatty acids) in compositions of 30:70 and 50:50. Several science flights were performed, during which the DC-8 regularly crossed the A320 plume at distances between 4 and 30 km. The optical particle counter FFSSP (Fast Forward Scattering Spectrometer Probe), positioned next to a CO_2 inlet on the DC-8 fuselage, was optimized to measure the ice particle concentrations in the contrails. In summary, over 450 contrail encounters were evaluated at flight altitudes between 7.8 and 11.6 km. The experiment provides an extensive, new contrail dataset to investigate basic formation processes and sustainable alternative fuel effects.

Dependence on Temperature and Humidity

The wide range of measurements, at varying ambient conditions with high statistical quality, makes it possible to investigate the dependence of contrail ice microphysics and extinction on ambient temperature and humidity. Ice number concentrations and contrail extinction coefficients are largest at altitudes near 9.5 km, typical for short- and medium-range air traffic. At higher altitudes near 11.5 km, low ambient water vapor concentrations lead to smaller contrail particle sizes and lower extinction coefficients.

Soot activation fractions in contrails formed at varying ambient temperatures are derived of soot and apparent ice emission indices (see Figure 1). At altitudes below 8.2 km, we observed contrails formed under incomplete soot activation near the contrail formation threshold temperature (Schmidt-Appleman criterion). Presented data are based on Bräuer et al. (2021).

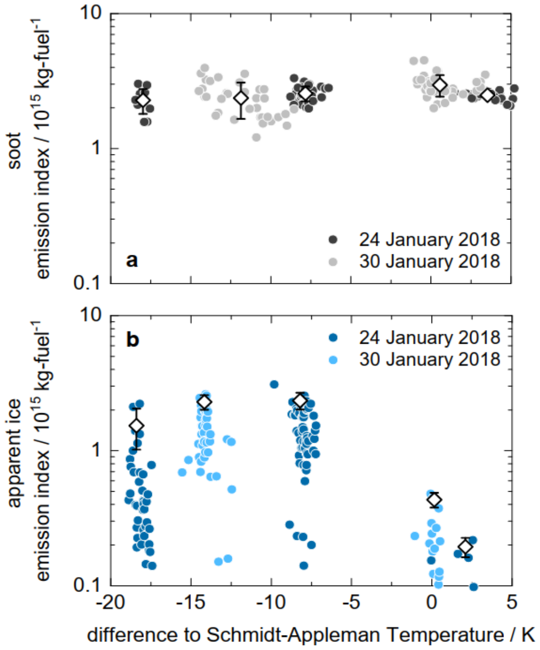

Figure 1. Emission indices (EI) versus the difference between ambient temperature and Schmidt–Appleman temperature. (a) Non-volatile particulate matter EI. Diamonds show the mean values. (b) Apparent ice EI. Diamonds show the mean upper 15%.

Biofuel Effects

In addition, we show apparent ice emission indices and optical contrail parameters for fuels of varying aromatic content. Apparent ice emission indices were reduced at a maximum of 70% for a sustainable alternative jet fuel compared to the reference fuel. Therefore, we proof that aviation's climate impact could be considerably reduced by the use of jet fuels with low aromatic content.

References

Bräuer et al. (2021) *Airborne Measurements of Contrail Ice Properties – Dependence on Temperature and Humidity,* Geophysical Research Letters.