Project:	1033
Project title:	Luftverkehr, Zirruswolken und Klima
Project leader:	Dr. Ulrike Burkhardt (DLR-Institut für Physik der Atmosphäre)
Report period:	2024.01.01 - 2024.12.31

2.1 Klimawirkung von Kondensstreifen für neue umweltfreundliche Antriebsformen

The project investigates the climate impact of contrail cirrus caused by new forms of propulsion and, therefore, contributes to the development of mitigation strategies.

2.1.1 Liquid hydrogen combustion (H2C)

Responsible: Weiß-Rehm (b309218), Burkhardt (b309022)

We implemented a new ice nucleation parameterization in ECHAM5-CCMod to calculate ice nucleation within contrails when using H2C as propulsion system. As opposed to kerosene combustion no soot aerosols are emitted when using H2C. The new parameterization assumes ice nucleation to happen on ambient mixed-in aerosols only and is able to treat several aerosol modes separately. We performed sensitivity studies varying the number of background aerosol modes considered within the parameterization (Figure 1). Assuming aerosol concentrations as estimated for SSP245 for 2050, the simulations for H2C shows a strong reduction in radiative forcing associated with contrail cirrus of around 60%, significantly more than can be achieved when using sustainable aviation fuel (SAF).

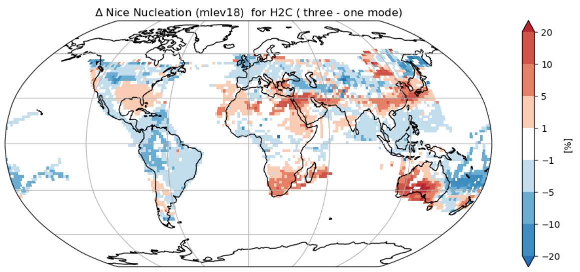

Figure 1: Difference in ice nucleation at main flight level using one mean or three individual background aerosol modes.

2.1.2 Brennstoffzelle (H2FC)

Responsible: Bickel (b309139), Burkhardt (b309022)

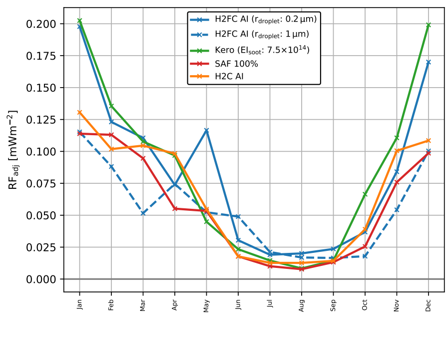

Figure 2: Annual cycle of Radiative Forcing for different propulsion systems.

We investigate the climate impact of contrail cirrus induced by fuel cell powered aircraft (H2FC) for the year 2050. The contrail formation process is fundamentally different from the standard kerosene combustion case, as fuel cells emit no condensation nuclei (e.g. soot), meaning that the condensation process is largely dependent on ambient aerosols.

To further improve this all-important condensation and freezing process we implemented a new AI based parameterization, developed within project 832. H2FC climate simulations were performed for droplet emissions with an initial size of 0.2 μm and 1 μm, which result in a larger Radiative Forcing for the 0.2 μm case (see Fig. 2). Overall, the radiative impact is strongly reduced in the summer month due to the applied regional air traffic scenario where aircraft fly at lower altitudes. A comparison with other propulsion systems revealed that the RF of the H2FC 0.2um case is comparably sized as a kerosene scenario with reduced soot emissions. In contrast the RF of the H2FC 1 µm case is further reduced and has about the same size as the SAF (sustainable aviation fuel) and H2C scenario. Thus, it would be beneficial for future mitigation efforts to target the emission of relatively large ice crystals in case of fuel cell powered aircraft.

2.1.3 GCM simulations for development of a statistical response model

Responsible: Burkhardt (b309022)

Based on the work within subprojects 2.1.1 and 2.1.2 we performed a large number of simulations with ECHAM5-CCMod to determine contrail cirrus properties and associated radiative forcing that are used to build the statistical response model AirCLIM within DKRZ-project 1062. In particular, we performed simulations for both, short and medium-range and regional only air traffic, using normal kerosene, SAF and H2C for the year 2050. We varied the amount of air traffic in order to explore the saturation in contrail cirrus properties with the ever increasing amount of air traffic.

2.2 Evaluierung hochauflösender Simulationen mit Kampagnendaten und Satelitendaten

Responsible: Verma (b309131), Burkhardt (b309022)

In this subproject, we studied the variability in contrail formation and properties using the high-resolution ICON-LEM including a parameterization for contrail ice formation (Verma and Burkhardt [2022]) and using ECMWF initial and boundary conditions during the ECLIF3 campaign in the Mediterranean. We ran several simulations with shifted flight tracks due to a slight forecasting error in the position of a frontal system. We studied differences in contrail properties when using Jet A1 fuel and HEFA fuel for the ECLIF3 campaign day, 16^{th} April 2021. The simulations show a large variability of contrail cirrus life cycles connected with the atmospheric variability and aircraft emission (Figure 3). Contrails formed from Jet A1 fuel use have a higher ice number concentration than those formed from HEFA fuel (Figure 3). The ice crystal number concentration in the HEFA contrail decays faster than in the Jet A1 contrail which leads to a relatively short contrail life times.

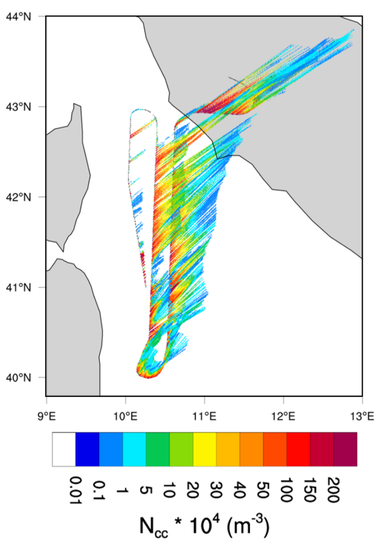

Figure 3: Evolution of ice number concentration during life cycle of contrails (N_{cc} (m^{-3})) formed along the flight path using Jet A1 fuel.

References

P. Verma and U. Burkhardt. Contrail formation within cirrus: Icon-lem simulations of the impact of cirrus cloud properties on contrail formation. *Atmospheric Chemistry and Physics*, 22(13):8819–8842, 2022. doi: 10.5194/acp-22-8819-2022. URL https://acp.copernicus.org/articles/22/8819/2022/.