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Multi-aircraft measurement campaigns on alternative fuel in aviation – a transatlantic collaboration

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We report on measurements of gas and particle emissions of jet engines during ground and flight tests and the investigation of contrail formation and properties in the wake of aircraft for alternative jet fuels. The alternative fuels used include various blends of JetA1 with synthetic Fischer-Tropsch fuels and biofuels, as well as a fully synthetic fuel. The ground measurements focused on the determination of emission indices for ICAO LTO (Landing and Take-off) power settings and additional power settings reflecting cruise conditions. The flight tests included measurements in the wake of source aircraft in the near-field (∼100-200 m) and far-field (∼10-20 km) for different fuels, cruise altitudes, power settings and for conditions with and without contrail formation. In addition to the tests with alternative fuels, also emissions and contrails of commercial aircraft equipped with novel low-emission LEAP (Leading Edge Aviation Propulsion) engines were studied.
Alternative fuels contain near-zero levels of aromatics and sulfur which are mainly responsible for the formation of soot particles and volatile aerosols during combustion and in the expanding emission plume, respectively. Aviation-related soot emissions play a crucial role in the formation of contrails. The number of soot particles emitted per kilogram of fuel burnt determines the initial number and size of ice crystals in contrails and thus the radiative properties of aviation-related cloudiness. Emissions of volatile aerosols by aircraft are suggested to alter the radiative properties of liquid clouds in the troposphere.
The ground and flight tests were performed during three campaigns at the NASA Armstrong Flight Research Center in Palmdale, California in 2014, the German Air Base in Manching in 2015, and the USA/NATO Air Base in Ramstein in 2018. All campaigns were conducted in a close collaboration between DLR and NASA. The aircraft involved included the DLR ATRA (Advanced Technology Aircraft) Airbus 320 and Falcon 20, and the NASA DC8 and Falcon HU25. In the campaign in Palmdale also the Canadian NRC participated with a CT133 aircraft.
The joint flights were conducted in restricted air space. The source and measurement aircraft flew race tracks with varying distances, speeds and altitudes. A real time display of wind-advected emission trails of the sources aircraft and selected gas and particle measurements aided in plume detection. The measurement strategy and main results from the joint campaigns will be presented including the observations that blends with 50% alternative fuel reduce emissions of non-volatile particles (soot) by 30 to 70% at cruise (Moore et al., NATURE, 2017).