

Effects of photochemical aging on the chemical and optical properties of exhaust emissions from a small-scale jet engine burner

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Aviation contributes to local and remote air pollution by emitting ultrafine particles and gaseous pollutants. Especially the compositions of long-transported, atmospherically aged exhausts remain poorly described, even though they may cause major health effects while also influencing the radiative forcing in the atmosphere. Here, our aim is to examine the impacts of photochemical aging on the jet engine exhaust emissions using kerosine-based jet fuel JP-8. The laboratory experiments were performed at the University of Rostock with a test rig containing a combustion chamber of an original small jet engine. The selected stable operation condition was determined so that the fresh emissions were comparable to those of an average land-and takeoff cycle of a commercial aircraft. Photochemical aging was conducted using the Photochemical Emission Aging flow Reactor (PEAR [1]), with hydroxyl radical exposure equivalent to roughly 2 days of atmospheric aging. Further tests at different exposures (0.5 – 7 days) were also performed. Online methods included, for example, high-resolution aerosol mass spectrometer (AMS) and proton-transfer-reaction (PTR-)ToF-MS for analysis of the exhaust chemical composition, scanning mobility particle sizer (SMPS) for the particle size and number determination, 7-λ aethalometer for online assessment of the particle light absorption, and aerodynamic aerosol classifier (AAC) coupled with an SMPS for particle density assessment. Filter samples were employed for a total carbon analysis and determination of the light absorbance of the water-soluble organic carbon by ultraviolet-visible (UV-Vis) absorption spectrophotometry.

Fresh particle emissions were minor, and had bimodal particle size distributions mainly composed of sub-30 nm particles. Scanning electron microscopy imaging confirmed that there was no soot in the exhaust emissions. Photochemical aging led to notable particle growth by substantial secondary organic aerosol formation, which increased the total particle mass by a factor of ~300 while decreasing the size-dependent particle effective densities. Organic aerosol became increasingly oxidized as a function of exposure. Further, aging caused a significant increase in the light absorption by organic matter at lower visible wavelengths (e.g., ×10 at 365nm, based on the UV-vis). The potential climate impact of such secondary aerosol formation is further assessed by modelling of the radiative forcing efficiency based on the aethalometer and UV-Vis results.