Non-volatile PM emissions from an in-production aircraft jet engine determined according to the requirements of a new emission standard

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Aviation has been steadily growing since the early jet age, so have its effects on the environment because its growth outpaces measures taken to reduce emissions. Although CO_2 and NO_x emissions contribute most to aviation's environmental impacts, aircraft soot emissions pollute the air nearby airports and warm up the atmosphere because they strongly absorb sunlight and contribute to aviation-induced cloudiness. To better understand and predict them, researchers need representative measurement data. Such data are scarce, but will become available owing to the new emissions standard for non-volatile (nv) PM emissions from aircraft turbine engines. This standard requires engine manufacturers to report nvPM mass and number emissions for in-production engines. In this contribution, we estimate exit plane emissions of nvPM mass and number from a widely used turbofan engine type determined from measurements at certification-like conditions. We discuss these results with respect to previous approaches to estimate aircraft nvPM emissions for air quality and global impact assessment.

Engine exhaust sampling, measurement, and data analysis were done according to the current requirements for emissions certification (ICAO, 2008). Engine tests were performed in an engine test cell of SR Technics at Zürich airport, Switzerland using a conventional Jet A-1 fuel. The engine was operated on a descending power curve from takeoff to idle during several runs. A representative exhaust sample was drawn at the engine exit plane using a multi-orifice probe. Downstream of the probe, the sampling system delivered a raw exhaust sample to a measurement suite for gaseous pollutants and a diluted sample for measuring nvPM mass and number concentrations (Durdina et al., 2014). The nvPM concentrations were normalized as emission indices (EI, amount of pollutant per kg fuel burned).

EI of nvPM number (EI_n) and mass (EI_m) changed with engine power (Fig. 1). Whereas EI_m monotonically increased with thrust and peaked at maximum power, EI_n had a local maximum at idle and reached a plateau before maximum thrust due to particle coagulation. Since the sample in the standardized system is drawn over 30 meters of tubing before reaching the nvPM instruments, particle losses need to be taken into account. We corrected both nvPM mass and number data for losses due to thermophoresis and diffusion using a parametric model based on measured particle size distributions, effective density, and thermodynamic properties of the exhaust sample. The particle losses were highest at idle, characteristic by the smallest mean particle size (geometric mean diameter ~15 nm). We estimated up to doubled EI_m and an order of magnitude higher EI_n at the engine exit plane than calculated from the measured concentrations shown in Fig. 1.

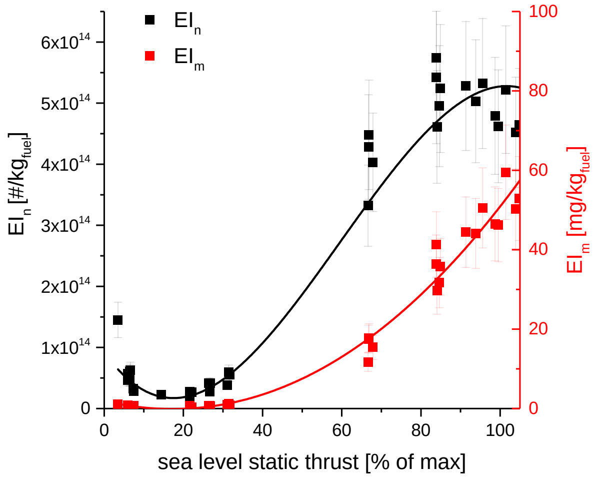

Figure 1. Emission indices of nvPM number and mass without correction for particle losses in the sampling system.

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