Improved Determination of Soot Mass Emissions from Aircraft Turbine Engines Using Particle Effective Density

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Introduction
- Aerosol sample is drawn from the engine exit plane to the instruments through more than 30 m long sample lines.
- Particles stick to the tube walls due to diffusional and thermophoretic effects.
- First principle model predicts well the particle transport efficiency in terms of particle number concentration.
- PM mass losses are more complicated - particle effective density changes with size.
- A reliable estimate of the PM at the engine plane essential for the emissions quantification and modeling.

Method
- Measure non-volatile PM mass (equivalent / refractory black carbon; BC).
- Measure particle size distributions (PSD).
- Fit lognormal distributions and find dependence on engine thrust.
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- Measure non-volatile PM mass (equivalent / refractory black carbon; BC).

Sampling and measurement
- CPM56/TH26/3 engine (Boeing 737, Airbus A320) tested in an engine test cell over the entire thrust range from idle to maximum power.
- Primary PM measurements on the diluted line (factor ~10:1; PM line).
- Ancillary PM measurements on the undiluted line (Annex 16 line).
- Up to 3 systems built to the same standard were deployed in parallel.

Particle transport model
- UTRC particle transport tool uses basic aerosol mechanics theory for particle transport efficiency prediction in the aircraft exhaust sample lines.

Results and outlook
- Line loss correction factor for PM mass ranged from 2.75 at engine idle to 1.35 at maximum power conditions using the size-dependent effective density.
- The unit density assumption provided a similar range of correction factors, but might have overestimated the losses at high thrust as well as underestimated at low thrust.
- Probe inlet temperature needs to be measured for a more accurate thermophoretic loss prediction.
- Future work will focus on intercomparison with models that do not use measured effective density and particle size.

Effective density: distributions and mean
- Power law fits of experimental data (CPMA mass over mobility equivalent volume).
- Increase with engine thrust: primary particle size growth and change of the internal structure from amorphous to crystalline (Liati et al., 2014, submitted to Env. Sci. Technol).
- Mean effective density decreased with engine thrust (GMD shifted to larger diameter particles that have lower effective density).
- Could be approximated as unit density (1000 kg/m³) for this engine.

Particle size distribution
- Geometric mean diameter (GMD) and the geometric standard deviation (GSD) determined from the lognormal fits increased linearly with engine thrust.