Optical properties of black carbon particles in aircraft engine exhaust

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INTRODUCTION

Black carbon (BC) emissions from aircraft engines have an impact on:
- Human health (vicinity to airports)
- Radiative forcing and climate (emissions in the upper troposphere)

Characterisation of major optical properties of BC (absorption ($\beta_{abs}$), scattering ($\beta_{scat}$), single scattering albedo (SSA)) required to estimate its climate effects.

METHODS

Experimental set-up:
- Single-orifice sampling probe
- Particulate matter instrumentation
- Raw gas instrumentation
- Smoke Meter

Location: SR Technics Test Cell, Zürich Airport
Duration: March – April 2017

Measured variables:

<table>
<thead>
<tr>
<th>Particulate matter</th>
<th>Gases</th>
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</thead>
<tbody>
<tr>
<td>Mass &amp; number</td>
<td>CO2, CO</td>
</tr>
<tr>
<td>Size &amp; density distribution</td>
<td>NOx, NO (NOx)</td>
</tr>
<tr>
<td>Smoke number</td>
<td>SO2</td>
</tr>
<tr>
<td>Optical properties</td>
<td>THC</td>
</tr>
</tbody>
</table>

Fuel properties:

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Aromatics (vol. %)</th>
<th>$H$ (mass %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet A1</td>
<td>17.9</td>
<td>13.8</td>
</tr>
<tr>
<td>HEFA 5%</td>
<td>17.1</td>
<td>13.8</td>
</tr>
<tr>
<td>HEFA 10%</td>
<td>16.2</td>
<td>13.8</td>
</tr>
<tr>
<td>HEFA 26%</td>
<td>13.2</td>
<td>14.2</td>
</tr>
<tr>
<td>HEFA 32%</td>
<td>11.3</td>
<td>14.3</td>
</tr>
</tbody>
</table>

Optical instruments:

- Cavity Attenuated Phase Shift single scattering albedo monitor (CAPS PM$_{1,5,A}$, $\lambda = 530$ nm)
- Photo-acoustic Extinctiometer (PAX, $\lambda = 870$ nm)

RESULTS

Engine variability:

- Optical coefficients increase with thrust and particle size
- Large variability in emissions between different engines

Biofuel effect:

- 20% decrease in absolute BC mass
- Lower aromatic content in biofuel blends reduces particle emissions at all thrust levels
- 20% decrease in absolute BC mass at 95% thrust with HEFA blend of 32% in volume

SSA and BC mass:

- SSA range: 0.14 to 0.34 (lower at higher thrust)
- $\beta_{abs}$ at 870 nm provides good estimate for BC mass
- Increase in mass correlates with increase in particle size

CONCLUSIONS & OUTLOOK

- Measurements during routine engine runs are suitable for the study of the optical properties of BC from different engine types (with online NO$_x$ interference correction for CAPS)
- Increase in absorption and scattering with increasing engine thrust (also mass and GMD); Large variability between different engine types
- Clear decrease in emissions with HEFA blends at all thrust levels (absolute decrease of 20% in BC mass with HEFA blend of 32% in volume)
- Low SSA (0.1-0.3) indicating highly absorbing particles
- Future developments in measurement set-up: Catalytic stripper to investigate the presence of organics in the emissions

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