Optical properties of black carbon particles in aircraft engine exhaust

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INTRODUCTION

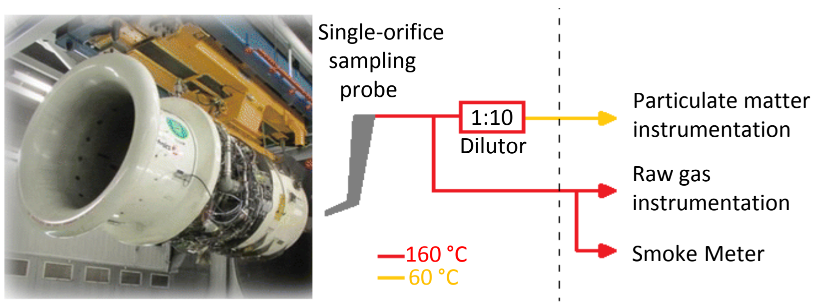
Black carbon (BC) emissions from aircraft engines have an impact on:

- **Human health** (vicinity to airports)
- **Radiative forcing and climate** (emissions in the upper troposphere)

Characterization of major **optical properties** of BC (**absorption** (b_{abs}), **scattering** (b_{scat}), **single scattering albedo** (SSA)) required to estimate its climate effects

METHODS

Experimental set-up:



Location: *SR Technics Test Cell, Zurich Airport*

Duration: *March – April 2017*

Measured variables:

Particulate matter	*Gases*
Mass & number	*CO_2, CO*
Size & density distribution	*NO_2, NO (NO_x)*
Smoke number	*SO_2*
Optical properties	*THC*

Fuel properties:

Fuel type	*Aromatics (vol. %)*	*H (mass %)*
Jet A1	*17.9*	*13.8*
HEFA 5%	*17.1*	*13.8*
HEFA 10%	*16.2*	*13.8*
HEFA 26%	*13.2*	*14.2*
HEFA 32%	*11.3*	*14.3*

Optical instruments:

Cavity Attenuated Phase Shift single scattering albedo monitor (CAPS PM_{SSA}, λ = 530 nm)

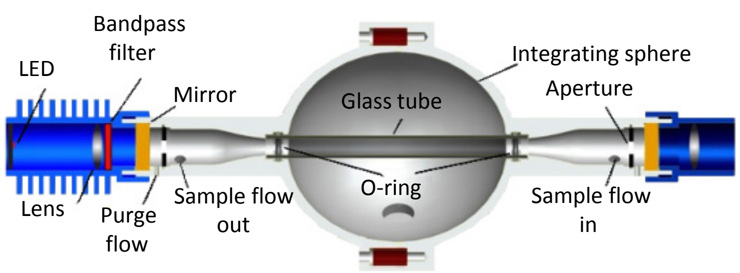
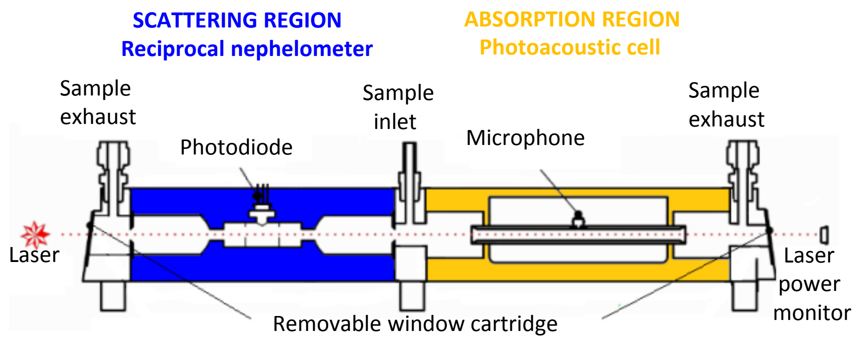
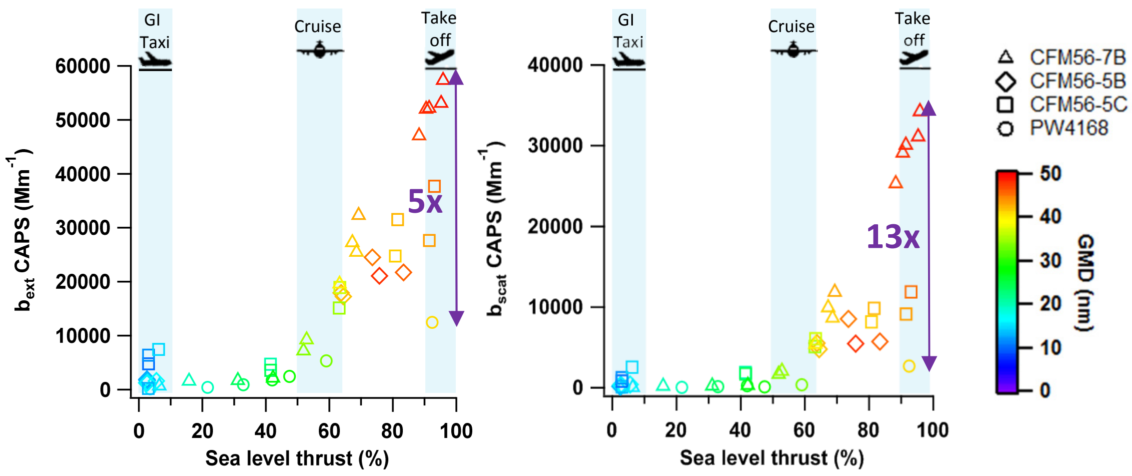


Photo-acoustic Extinctiometer (PAX, λ = 870 nm)



RESULTS

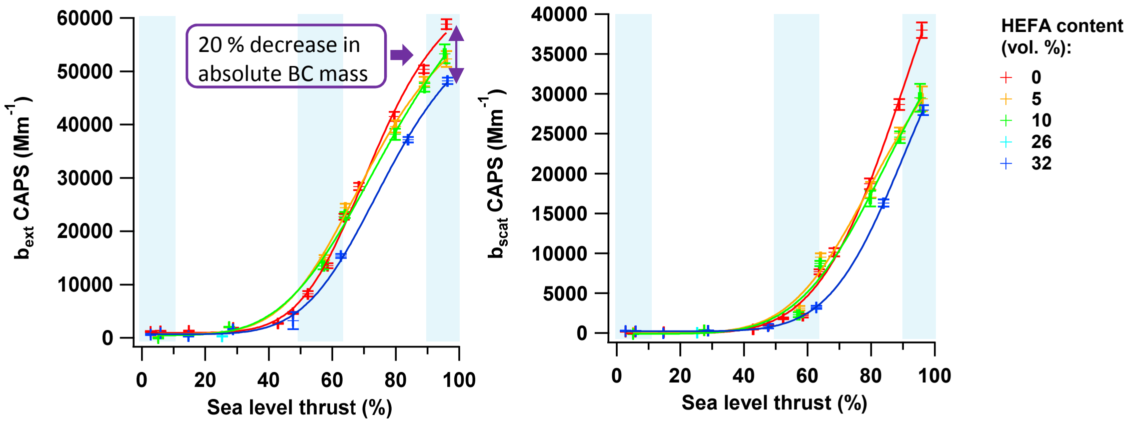
Engine variability:



→ Optical coefficients increase with thrust and particle size

→ Large variability in emissions between different engines

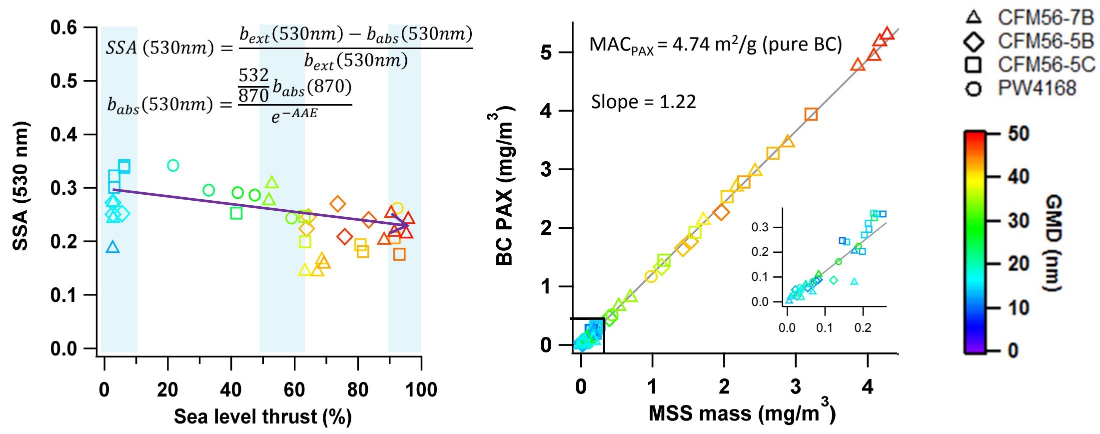
Biofuel effect:



→ 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)

→ b_{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_2 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
  Additional dilution step before CAPS

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