Fuel effects on aerosol microphysical properties

Bernadett Weinzierl[1,2], Eugenio D'Ascoli[2], Daniel Sauer[2,1], Jin Kim[1], Monika Scheibe[1], Hans Schlager[1], Richard Moore[3], Bruce Anderson[3]

1 Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

2 Meteorologisches Institut (MIM), Ludwig-Maximilians-Universität, München, Germany

3 NASA Langley Research Center, Hampton, Virginia, USA

NASA ACCESS-2 Data Workshop

Gaylord Palms Resort and Convention Center, Kissimmee FL

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DLR

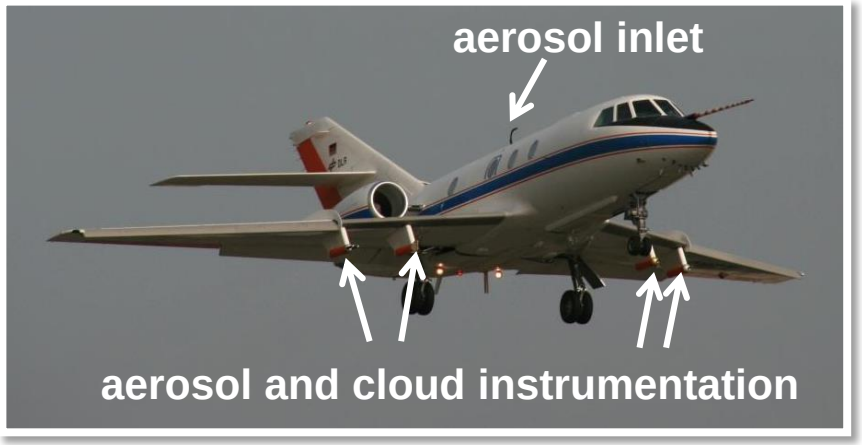
Objectives

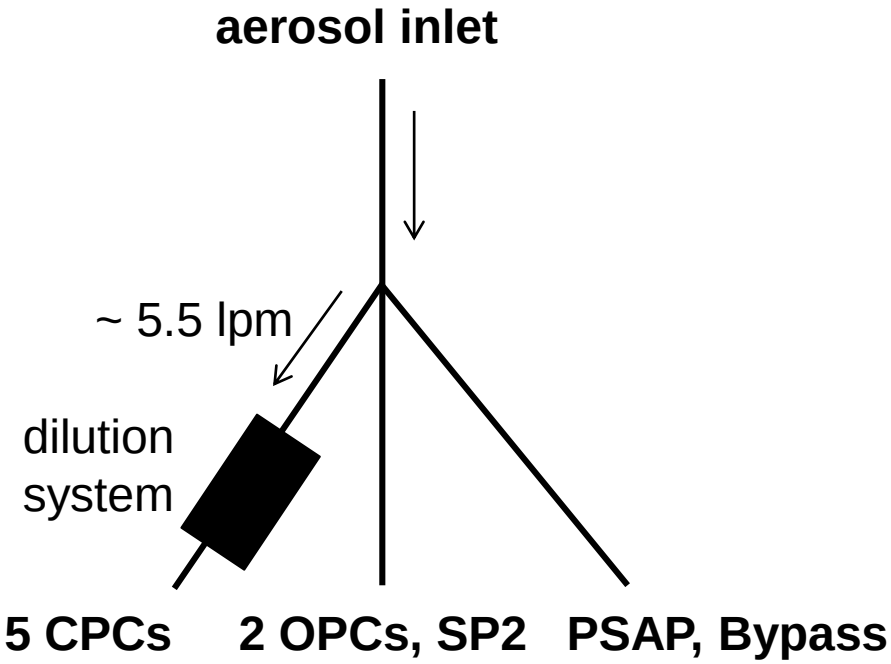
- Characterization of **particle emissions in different fuels** (Jet A and HEFA blend) at **different engine settings** at cruise altitude
- Determination of **particle emission factors**
- Analysis of **changes in the aerosol microphysical properties** of the total & non-volatile aerosol as a function fuel and engine setting
- Also necessary: in-depth lab **charaterization of the measurement system**

DLR Falcon aerosol instrumentation during ACCESS-2

Instrumentation	Measured quantity or property
Aerosol in-situ instruments operated inside the cabin behind an isokinetic inlet (~ D_p < 2.5 µm)	
Multi-channel **C**ondensation **P**article **C**ounter (CPC; 2 unheated, 3 heated channels)	Integral number concentration of ultrafine particles (0.004 < D_p < 2.5 µm) and non-volatile particle fraction
2-channel **O**ptical **P**article **C**ounter (Grimm SKY-OPC 1.129)	Total and non-volatile size distribution (D_p > 0.25 µm)
Thermo-denuder (255°C) + 3 CPC	Size distribution non-volatile Aitken/accumulation mode (0.01<D_p< 2.5 µm)
Thermo-denuder (255°C) + OPC	Non-volatile size distribution (0.25 < D_p < 2.5 µm)
Three-wavelength **P**article **S**oot **A**bsorption **P**hotometer (3-λ-PSAP)	Absorption coefficient at λ = 467, λ = 530 and λ = 660 nm
Single **P**article Soot Photometer (SP2)	Black carbon mass, single-particle coating thickness, mixing state
Aerosol in-situ instruments sampling at wing stations	
Passive **C**avity **A**ersol **SP**ectrometer (PCASP-100X)	Ambient state accumulation + coarse mode (nominal size range : 0.1 < D_p < 30 µm)
Ultra-**H**igh **S**ensitivity **A**erosol **S**pectrometer Airborne (UHSAS-A)	Aerosol size distributions (nominal size range: 60 nm < D_p < 1 µm)

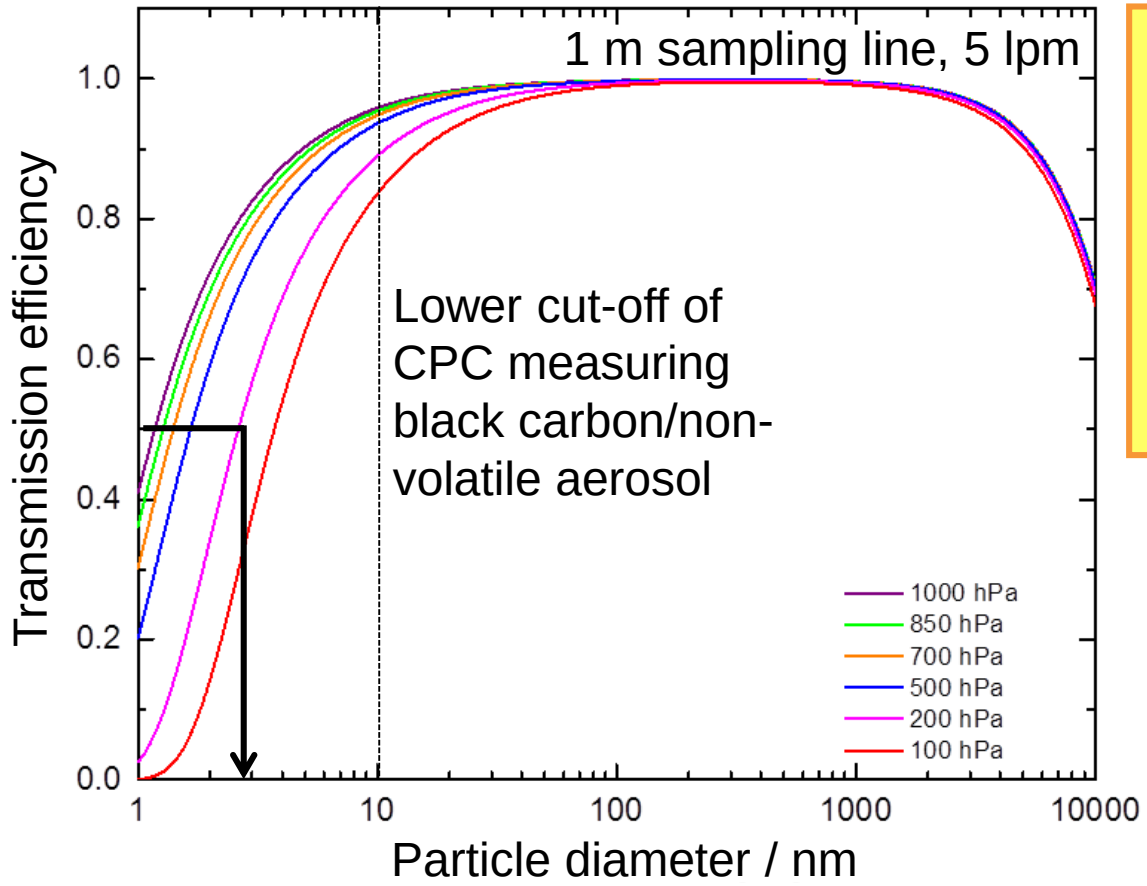
Instrument set-up inside the DLR Falcon





→ How do the sampling lines and the dilution system affect our results?

Diffusion and sedimentation losses in the sampling lines



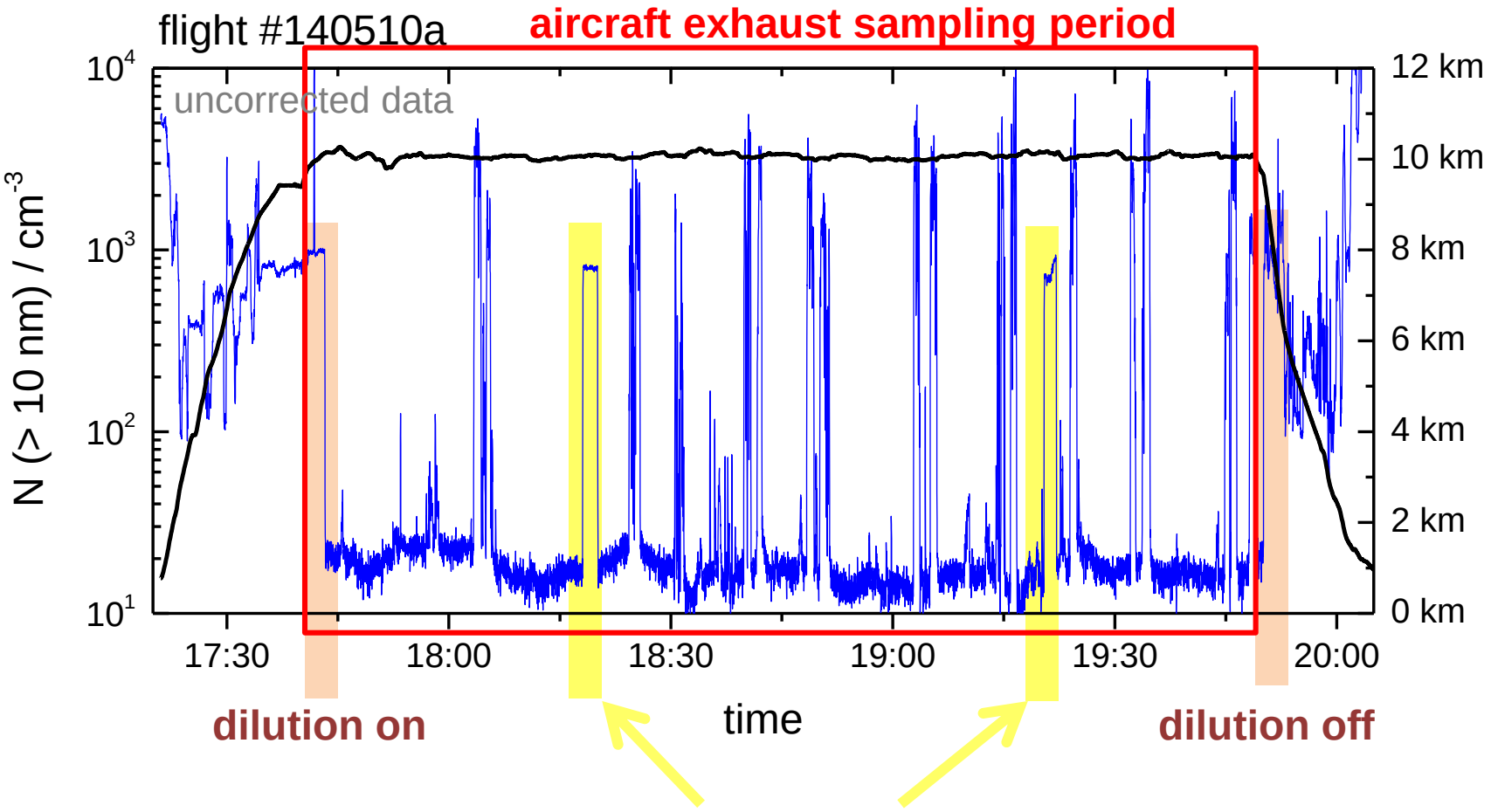
Cruise altitude (200 hPa):

→ 50% transfer efficiency for 3 nm particles

→ Sampling line losses negligible for black carbon measurements

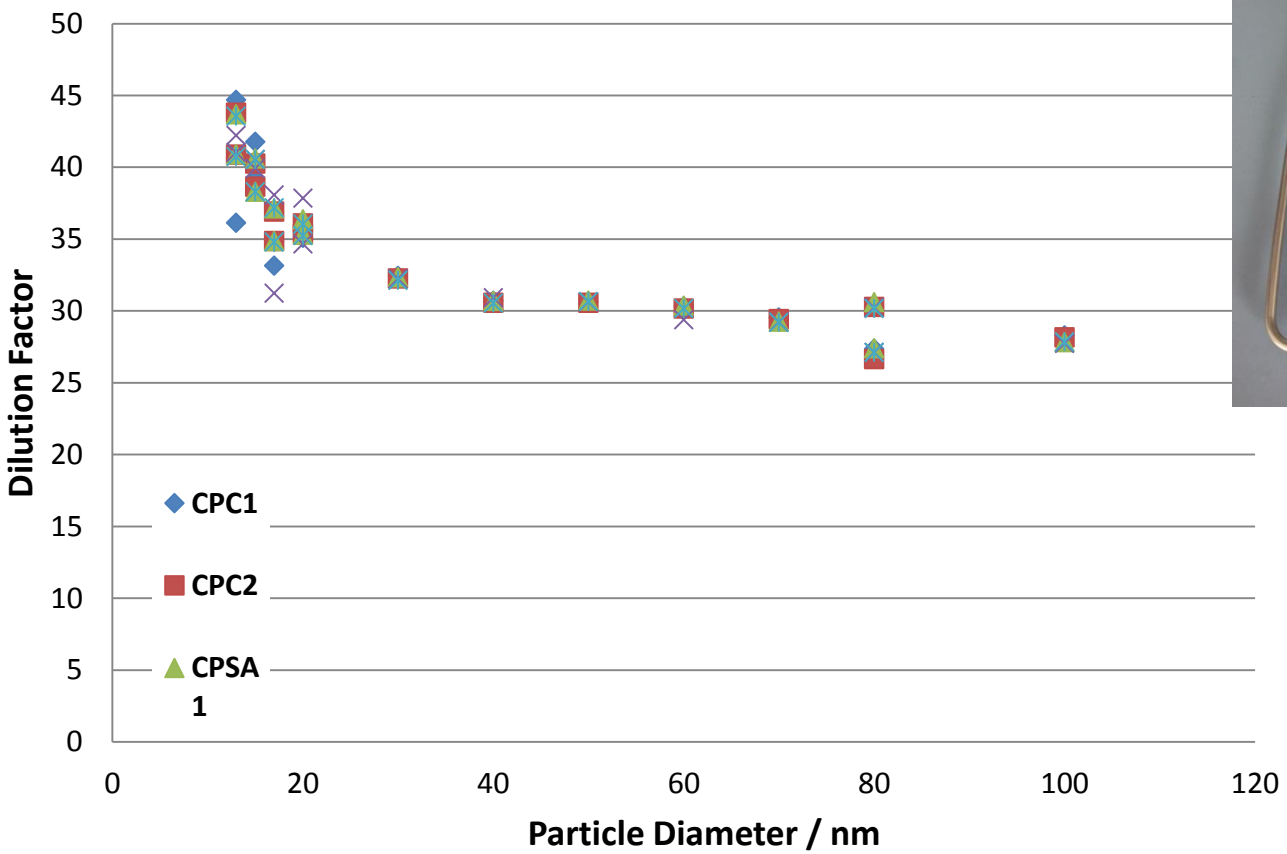
Bachelor thesis Melanie Kujukovic (LMU, 2015)

One example for exhaust measurements



In-flight testing of the dilution factor: 1:30 dilution

Laboratory testing of the dilution system



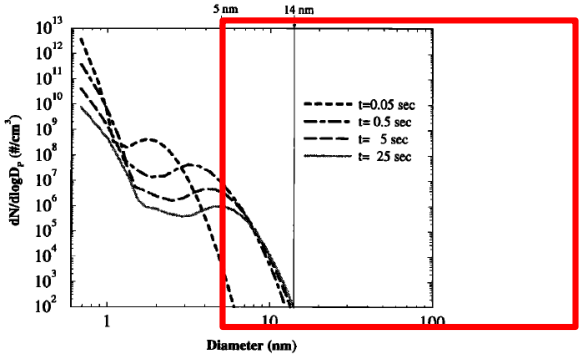
Down to ~20 nm, the **dilution factor** stays more or less constant at around **1:30** and then it increases with decreasing size due to increasing diffusion losses in the critical orifice inside the dilution system

Size-resolved fine mode aerosol

Total aerosol: N > ~ 5 nm, N > ~ 10 nm

> ~ 5 nm > ~ 10 nm inlet cut-off: ~2.5 µm

Note: this only detects a small fraction of the nucleation mode

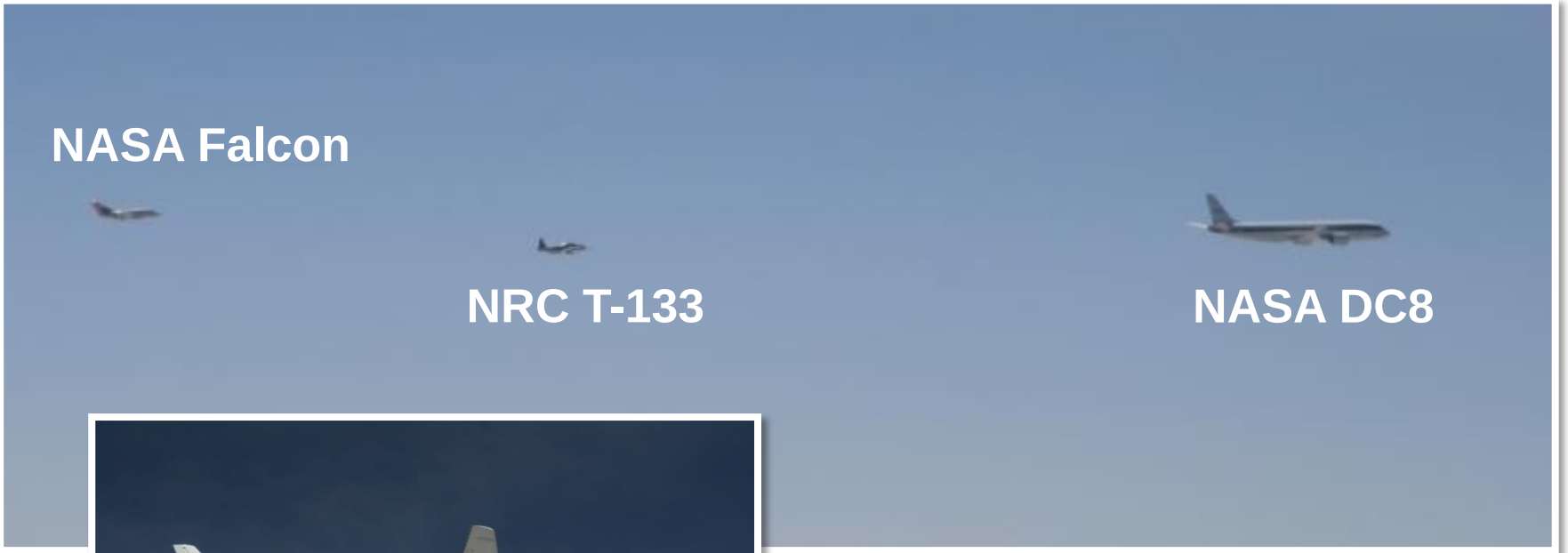


(Yu et al., 1999)

Black carbon/non-volatile particles: $N_{non\text{-}vol}$

> ~ 10 nm > ~ 28 nm > ~ 52 nm > ~ 85 nm (SP2) inlet cut-off: ~2.5 µm

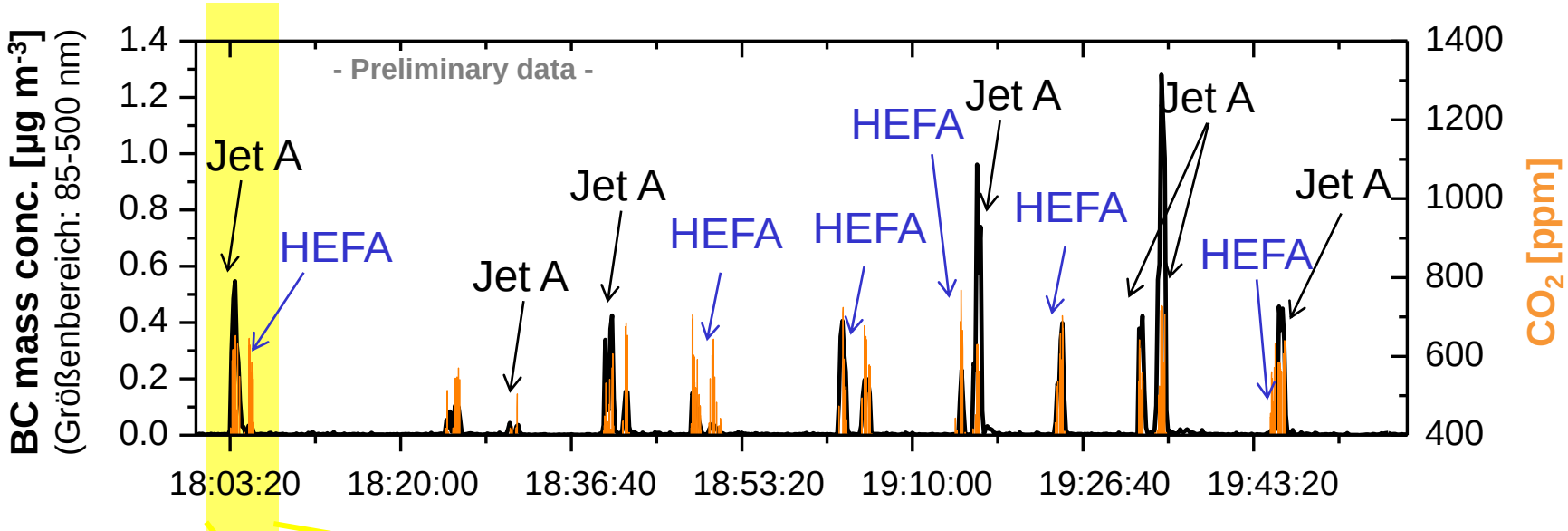
Results from measurements on 10 May 2014

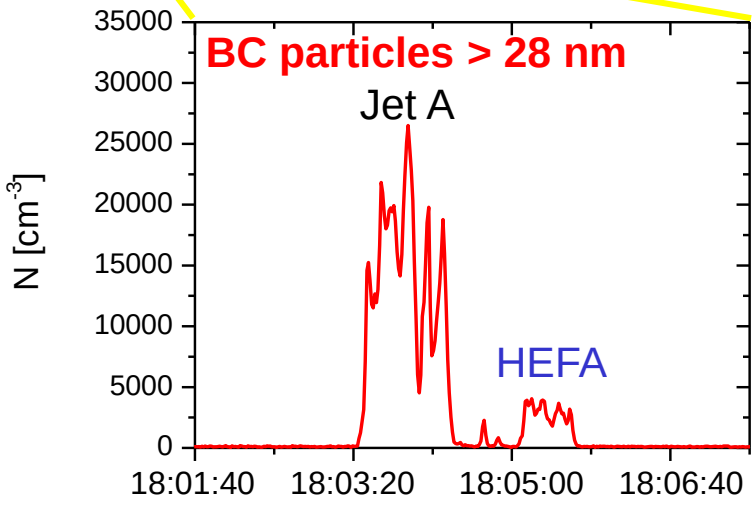


Note:

On 10 May 2014 no contrails were present, all aerosol measurements were done in „clear air“

Time series of black carbon number/mass conc. & CO2



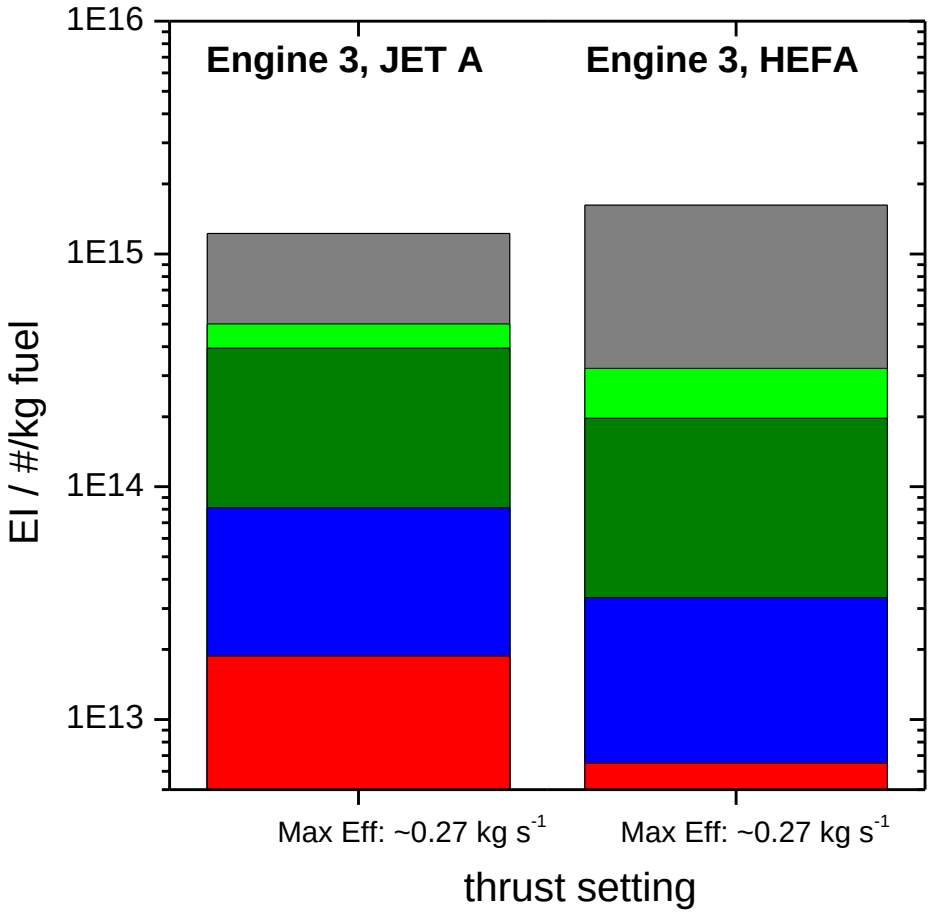


First results:

HEFA contain:

- Less (total) particles
- Less/smaller BC particles

10 May 2014: particle emission indices (engine 3)



Total aerosol:
N > 5 nm

N > 10 nm

Non-volatile aerosol:
$N_{non\text{-}vol}$ > 10 nm

$N_{non\text{-}vol}$ > 28 nm

$N_{non\text{-}vol}$ > 52 nm

→ Most size ranges: significant reduction of particle emissions

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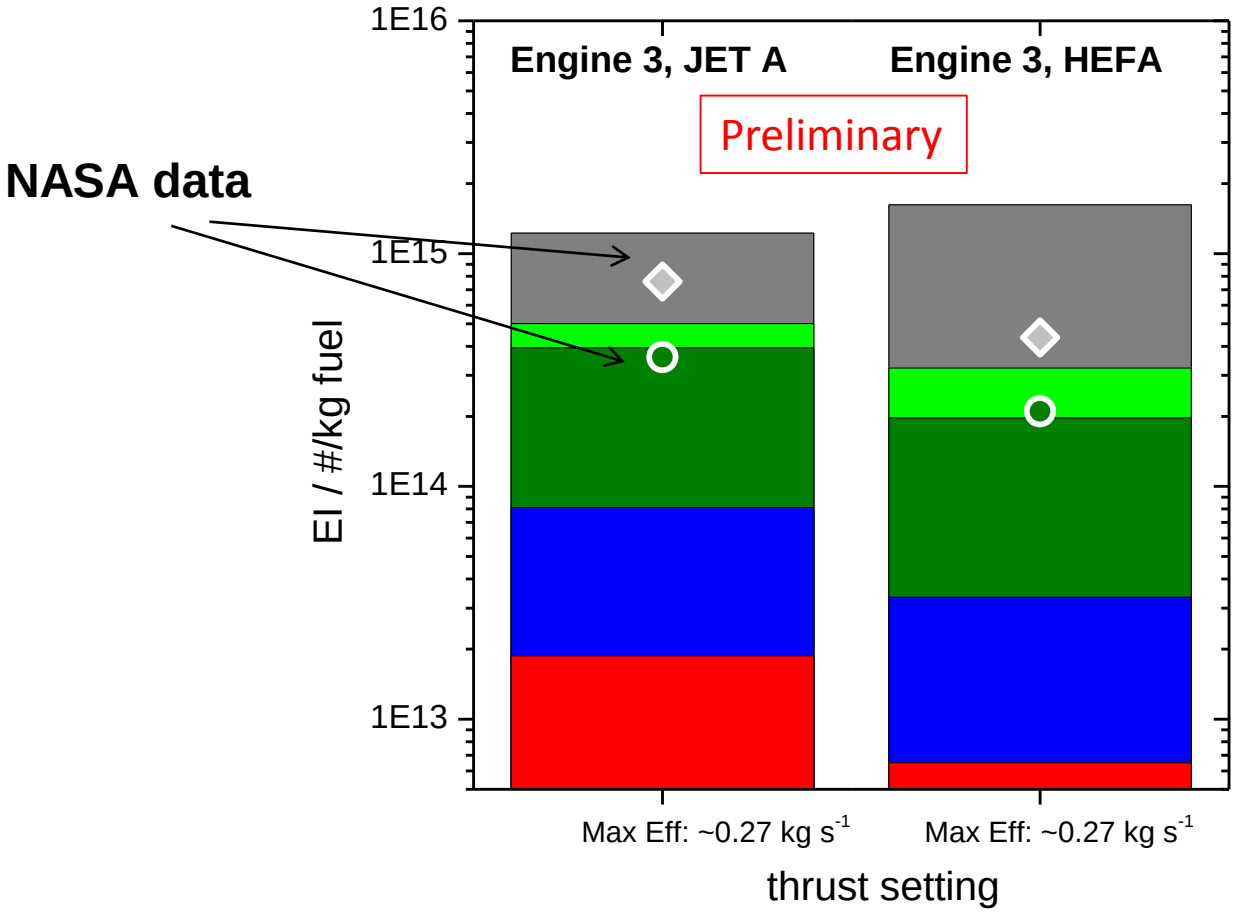

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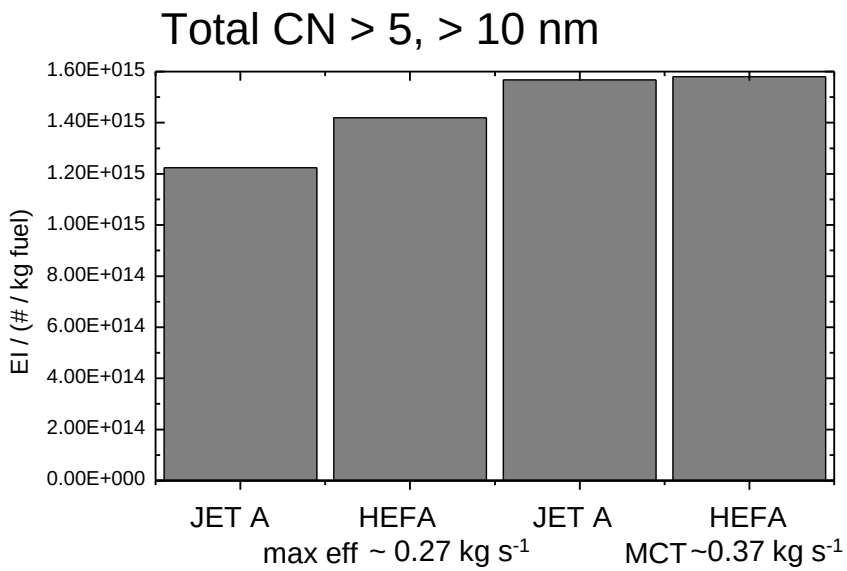
→ Most size ranges: significant reduction of particle emissions

10 May 2014: comparison of JET A versus HEFA blend



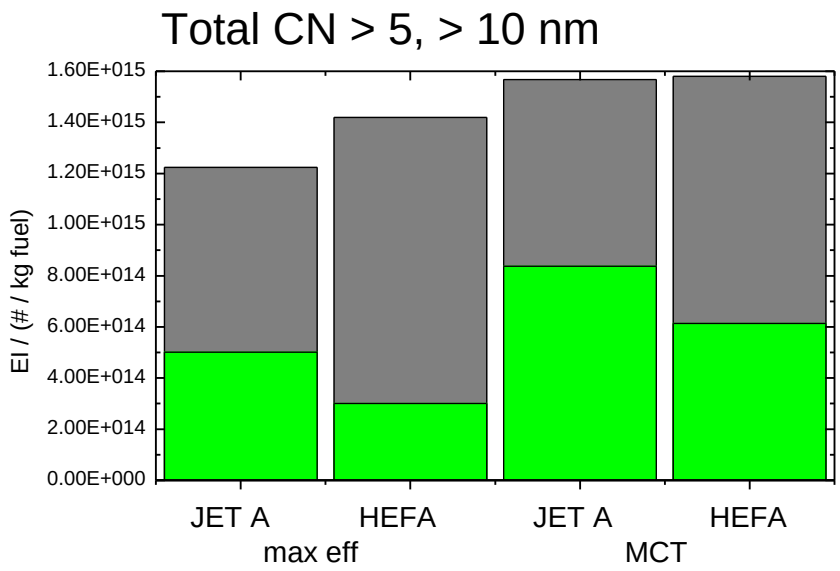
→ **Emission index for total particles > 5 nm similar for JET A and HEFA blend**

Reason: emission of ultra-fine particles is driven by the sulfur content of the fuel

Note: for the ultra-fine particles the plume age is also relevant (not considered here)

10 May 2014: comparison of JET A versus HEFA blend

ENGINE 3



→ **Emission index for total particles > 5 nm similar for JET A and HEFA blend**

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Note: for the ultra-fine particles the plume age is also relevant (not considered here)

10 May 2014: comparison of JET A versus HEFA blend

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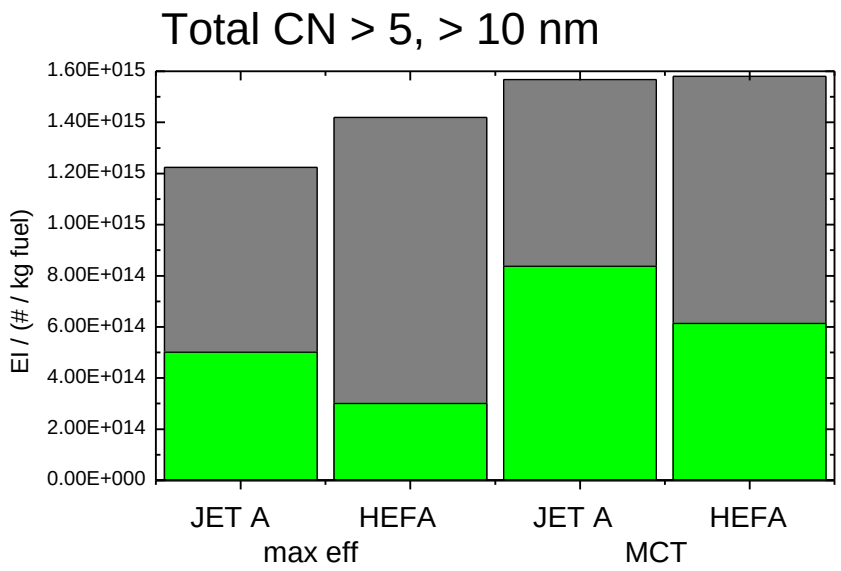

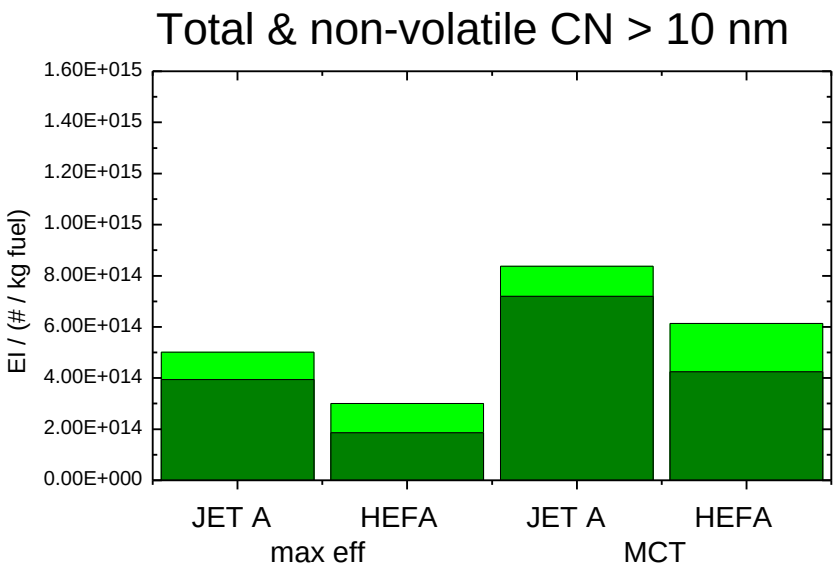

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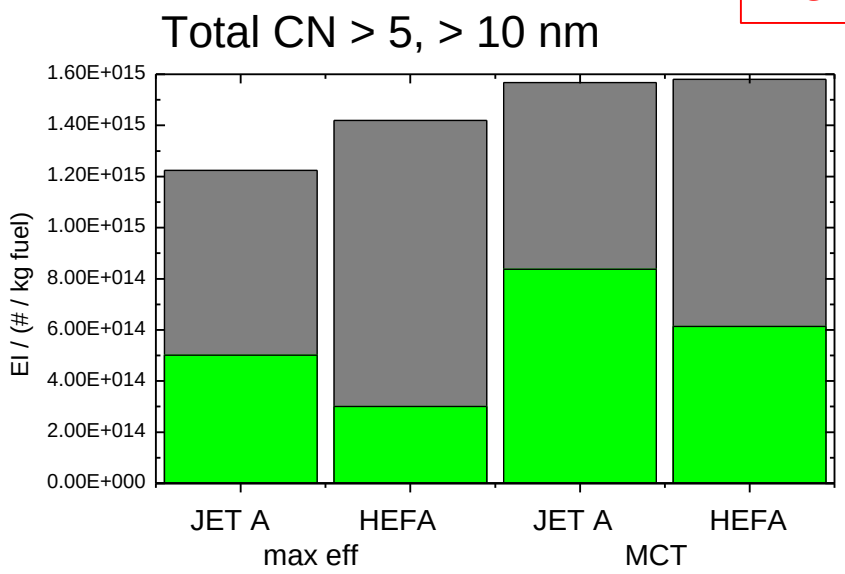
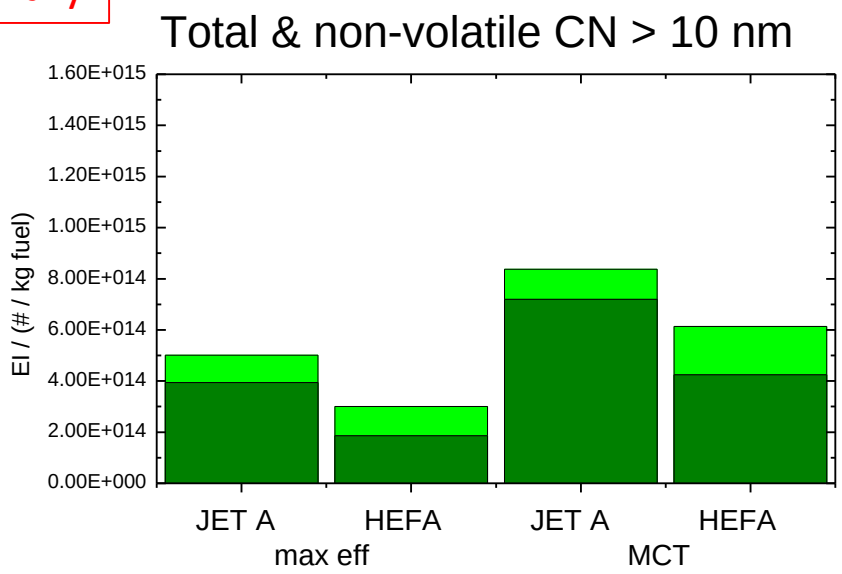
Preliminary

ENGINE 3





→ **Emission index for total particles > 5 nm similar for JET A and HEFA blend**

Reason: emission of ultra-fine particles is driven by the sulfur content of the fuel

Note: for the ultra-fine particles the plume age is also relevant (not considered here)

→ **62 – 86 %** of total particles > 10 nm are non-volatile, i.e. **particles > 10 nm are predominantly black carbon**

Reduction in particle emissions for HEFA blend (compared to JET A fuel)

	Total aerosol	**Black carbon** (increasing size) →		
Engine 2	N total > 10 nm	N non-vol > 10 nm	N non-vol > 28 nm	N non-vol > 52 nm
Max Eff	37%	47%	58%	63%
MCT	31%	38%	47%	55%

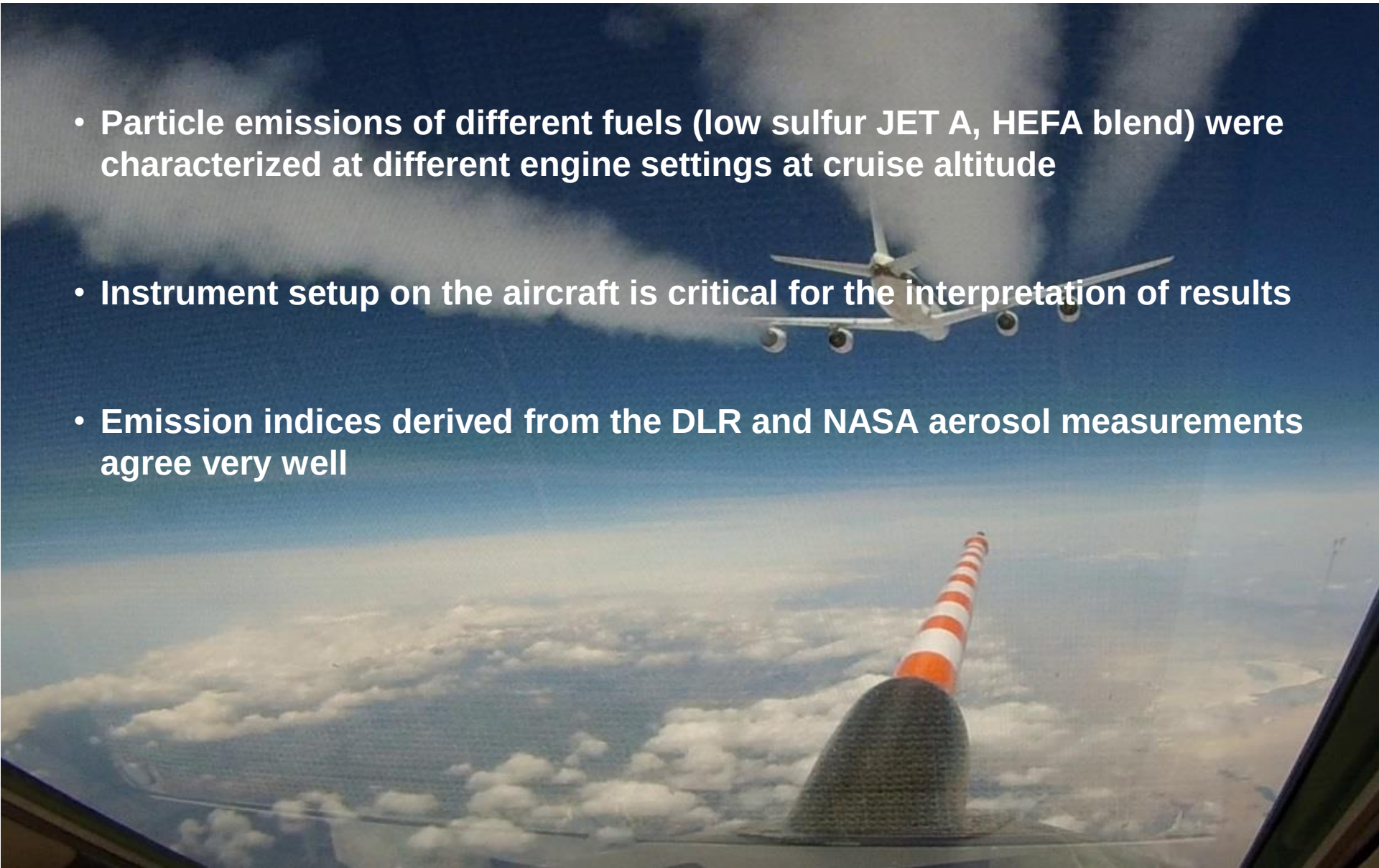
Engine 3	N total > 10 nm	N non-vol > 10 nm	N non-vol > 28 nm	N non-vol > 52 nm
Max Eff	40%	53%	62%	69%
MCT	27%	41%	50%	58%

Preliminary

→ Particle emissions are **reduced by ~ 30-60% for HEFA blend**

→ Largest reductions for the larger size range of non-volatile particles, i.e. the **HEFA blend contains fewer and smaller black carbon particles**

Summary



- **Particle emissions of different fuels (low sulfur JET A, HEFA blend) were characterized at different engine settings at cruise altitude**
- **Instrument setup on the aircraft is critical for the interpretation of results**
- **Emission indices derived from the DLR and NASA aerosol measurements agree very well**

Take home messages – effects of fuel type

- **EI_total (particle diameter > 5 nm):** **equal for HEFA blend and low-sulfur JET A**, because total number of particles in the exhaust is driven by the sulfur content
- **EI_10 (particle diameter > 10 nm):** particle emissions are **reduced by ~ 30-60% for HEFA blend** (most pronounced for max efficiency)
- Largest reductions for the larger size range of non-volatile particles, i.e. the **HEFA blend contains fewer and smaller black carbon particles**