Ground measurements on aircraft exhaust for a series of alternative jet fuels during the ECLIF and ND-MAX campaign

Tobias Schripp, Patrick Oßwald, Markus Köhler
DLR Institute of Combustion Technology, Chemical Analytics

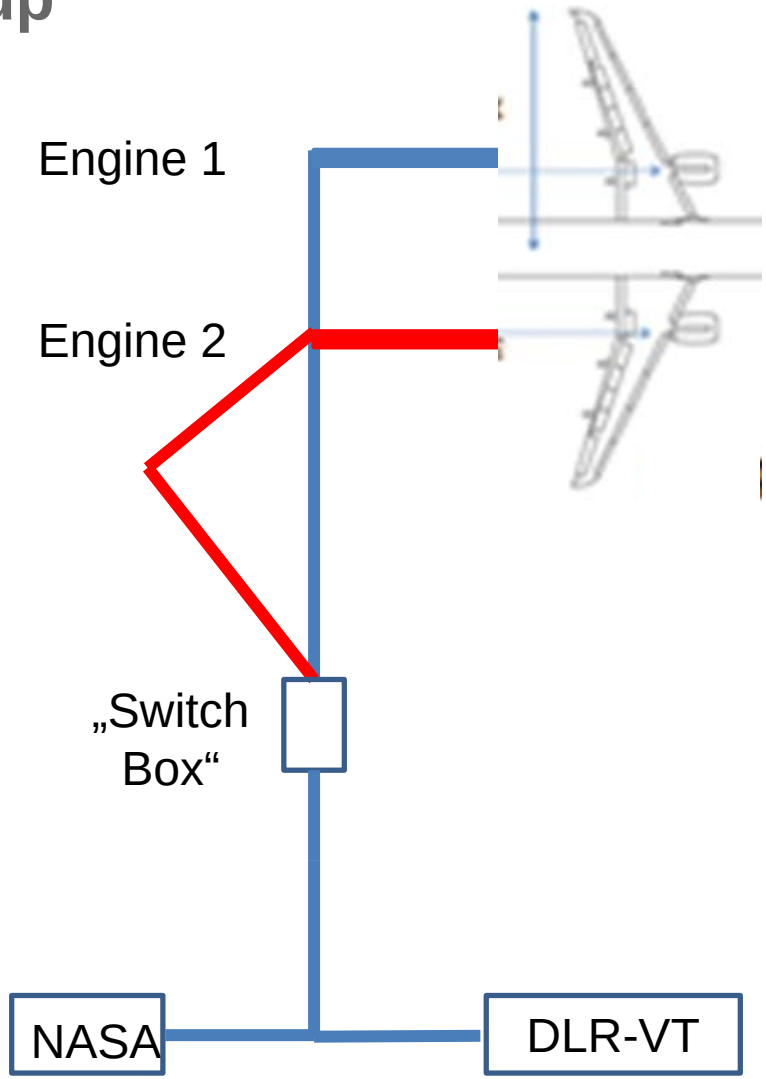
Prem Lobo, Joel C. Corbin, Gregory Smallwood
National Research Council of Canada

Ewan Crosbie, Claire Robinson, Michael Shook
NASA Aerosol Research Group

Emission & Climate Impact of Alternative Fuels (ECLIF)

- **2014** NASA-DLR Collaboration (DLR participating in NASA ACCESS (Alternative Fuel Effects on Contrails and Cruise Emissions) II)
- **2015** ECLIF Part 1: Impact of **aromatic content** in alternative fuels. Contrail measurements and ground measurements compared to fossil Jet A-1 (Falcon – A320 „ATRA“)
- **2018** ECLIF Part 2: Ground measurements and in-flight emissions & contrails measurements of HEFA blends with special focus on **naphthalene content** (NASA DC-8 – A320 „ATRA“)

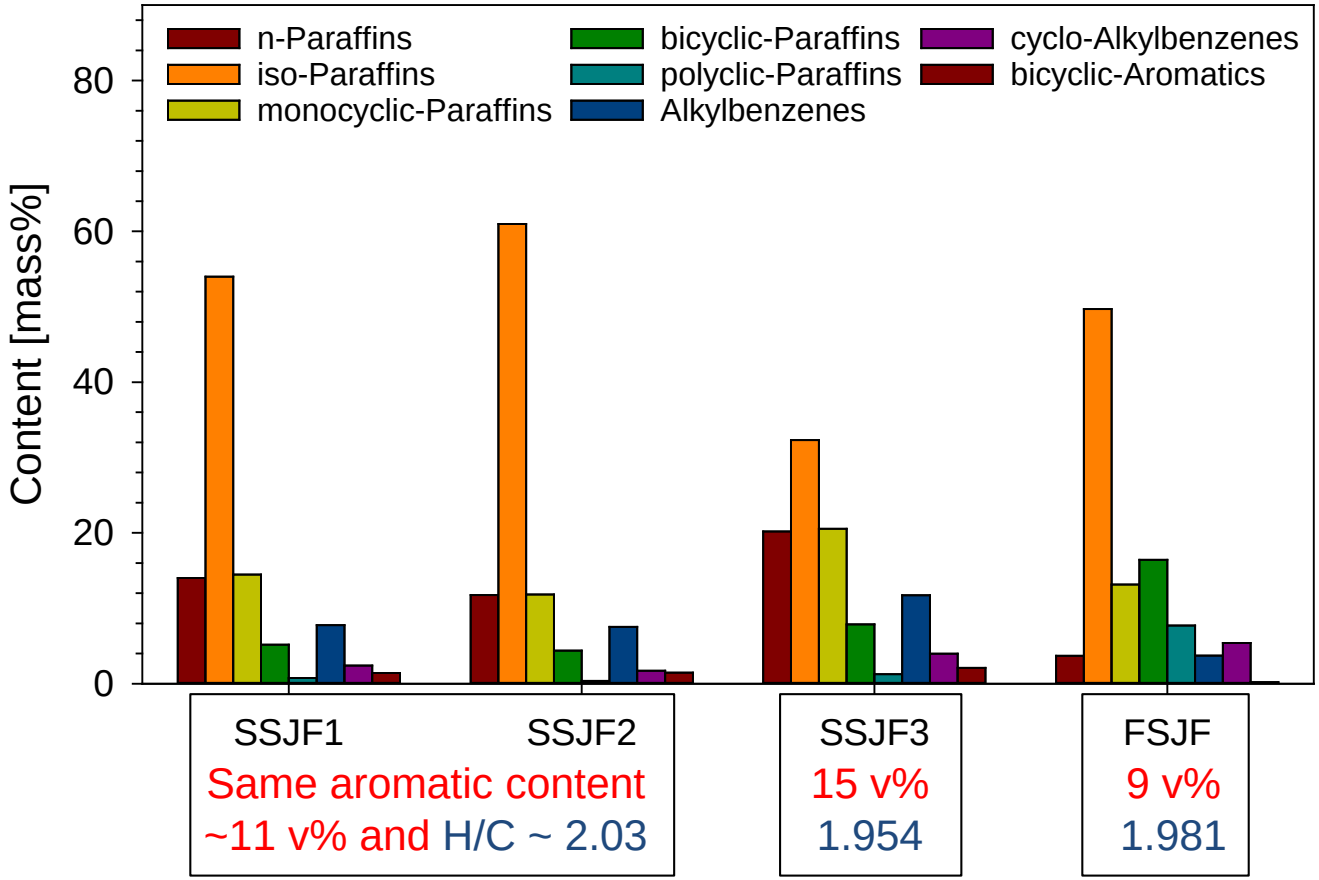
ECLIF Ground Measurements Setup

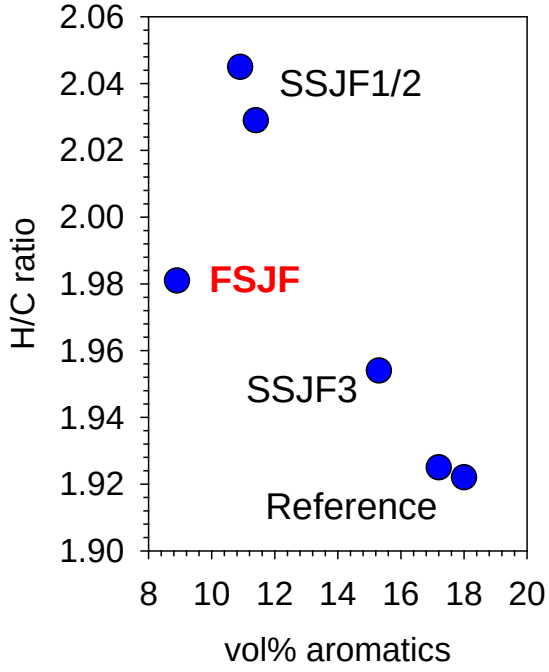


- A320 / V2527-A5 engines
- Two sampling probes (left/right engine), 30 m
- Ground measurement after each flight (no „warm-up“ artifacts or residual fuels)
- Two complementary sets of aerosol analytics by NASA and DLR with CPCs, EEPS, SMPS, etc.

ECLIF Fuels

- Two reference Jet A-1 (~18 v% aromatics; H/C ratio ~1.923)
- Four alternative jet fuels: fully synth. jet fuel (FSJF) and semi-synth. jet fuel 1-3

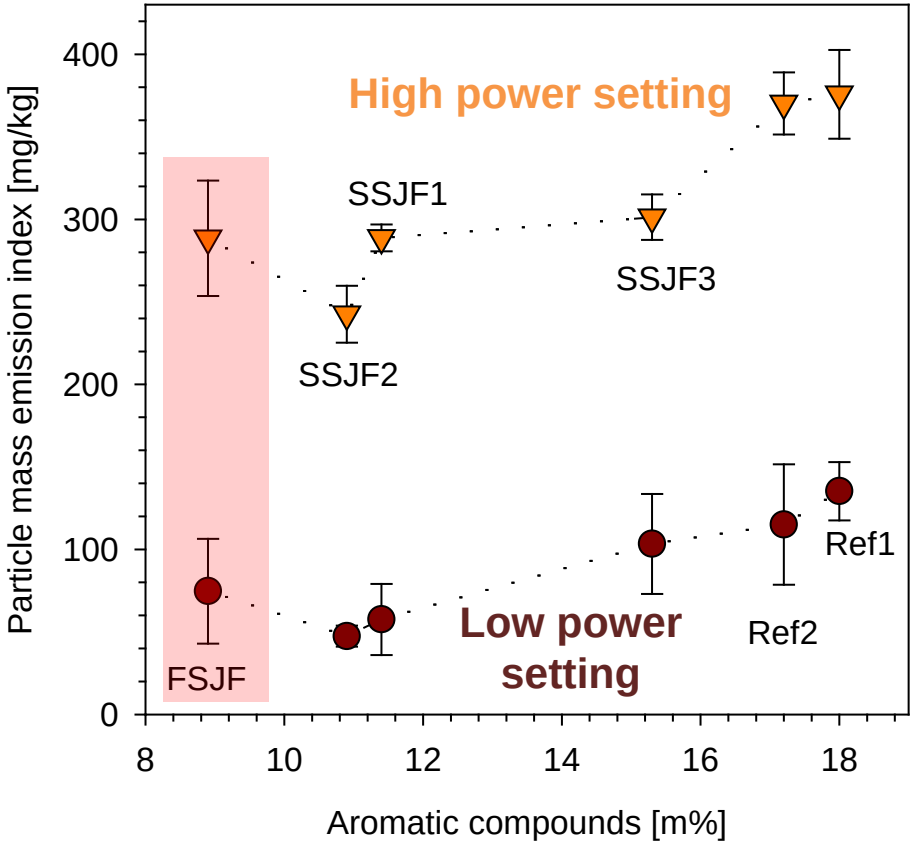


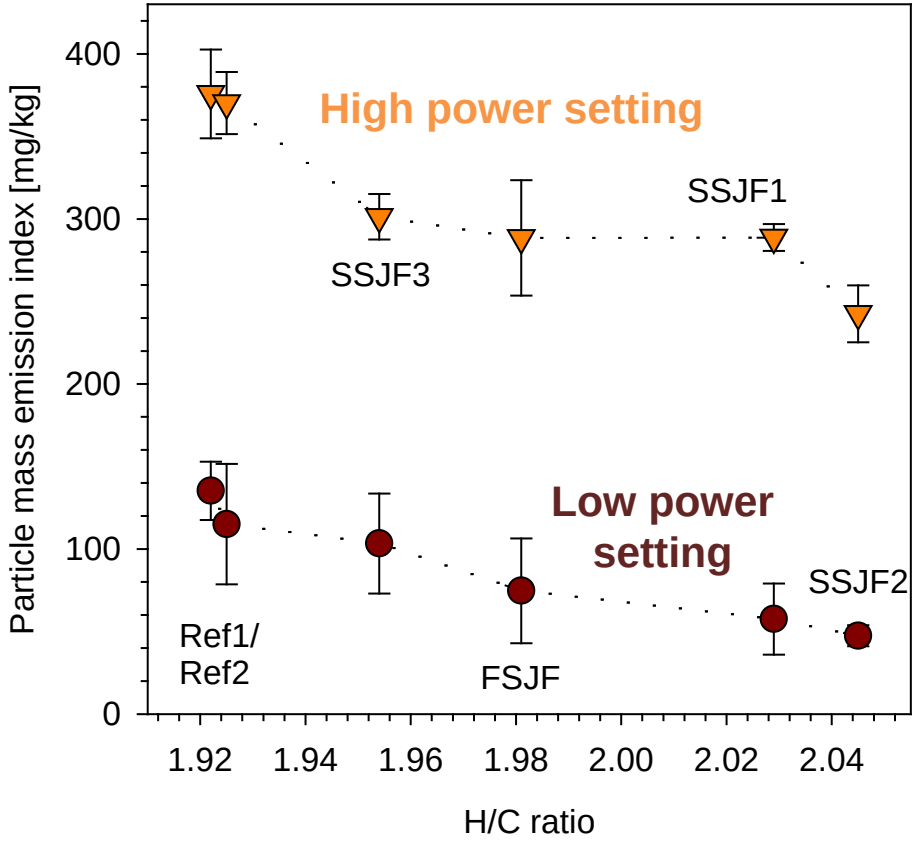


One alternative jet fuel with **low aromatics** but **high H/C ratio** (FSJF)

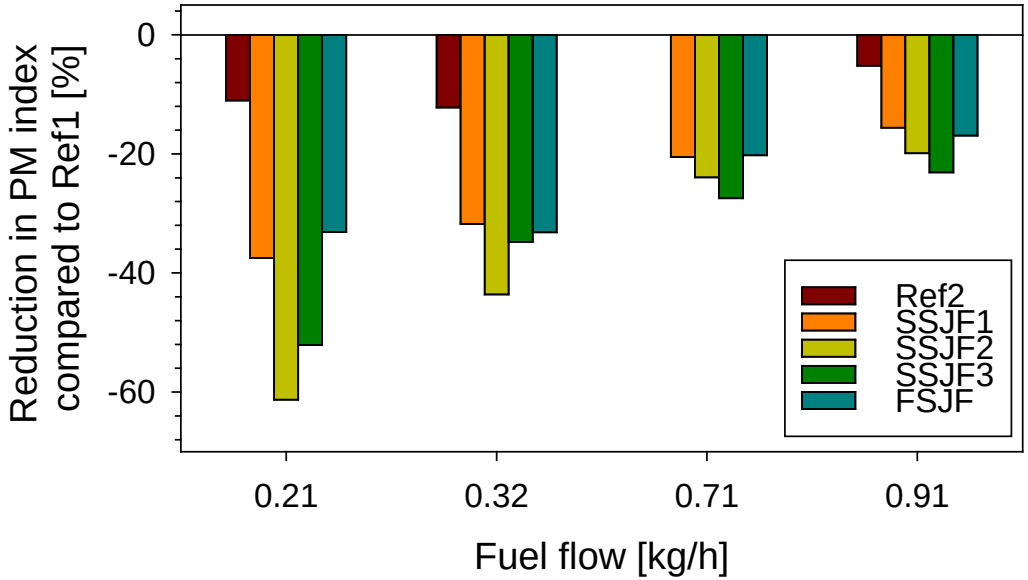
ECLIF Emission indices – Aromatics vs. H/C ratio

- Emission index development does not strictly follow the aromatic content but the H/C ratio
- Significant trend can be observed at high power settings (> 70% N1)

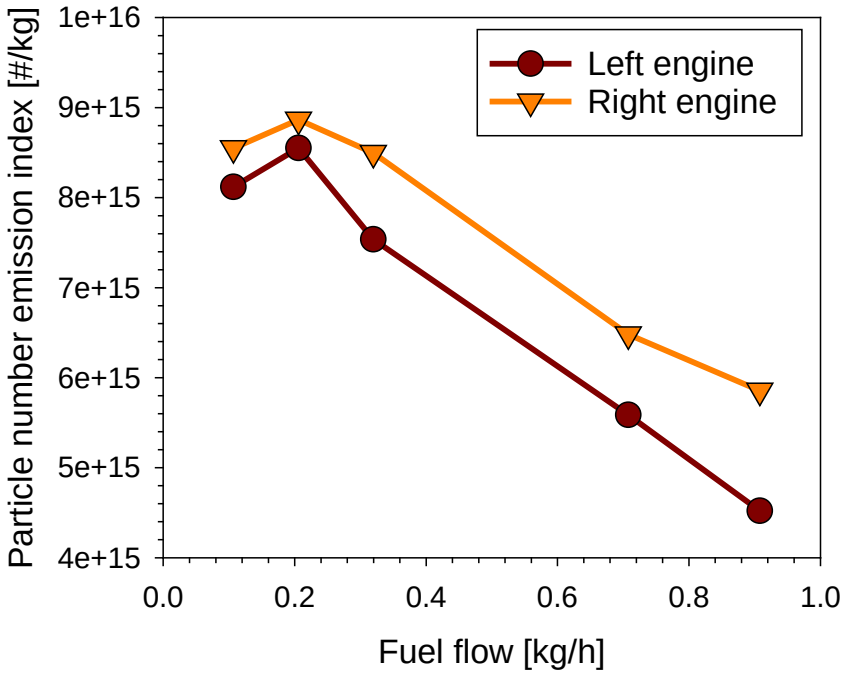




ECLIF Conclusion and lessons learnt



- Significant reduction of emitted particle mass (soot) for the different fuel blend



- The duration for each power setting (1 min) was not ideal for SMPS (nvPM) measurements
- Difference between both engines (l/r) was too high
  → Improved in the follow-up campaign

ND-MAX/ECLIF Fuels

Reference fuels / blending components
(≤ 100 ppm sulfur)

Jet A-1 (**Ref3**)
- "high" aromatics (~ 19 v%)
- "high" naphthalene content

Jet A-1 (**Ref4**)
- "low" aromatics (~ 15 v%)
- "low" naphthalene content

HEFA-SPK
(no aromatics)

Sust. alternative jet fuel 1 (**SAJF1**)
Ref3-blend

Sust. alternative jet fuel 2 (**SAJF2**)
Ref4-blend

Blending goals
- same aromatics (~ half of ref. fuels)
- different naphthalene content

Sust. alternative jet fuel 3 (**SAJF3**)
(intermediate properties)

- Can we measure a difference in soot emissions between SAJF1 and SAJF2?
- These combinations give insight into the impact of naphtalene content on the soot formation

ND-MAX/ECLIF Setup

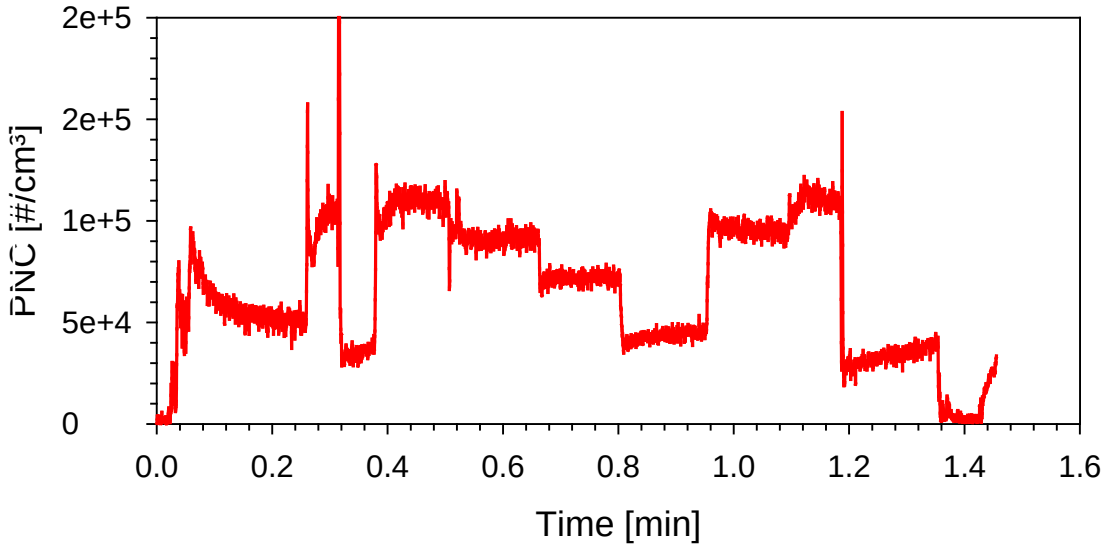
- A320 (ATRA) at 40 m distance from blast fence (probe position)
- Exhaust analysis performed by 6 science groups from a central manifold
- Instruments covered different types of particle counters and soot monitors (CPCs, EEPS, LII, CAPS, etc.)

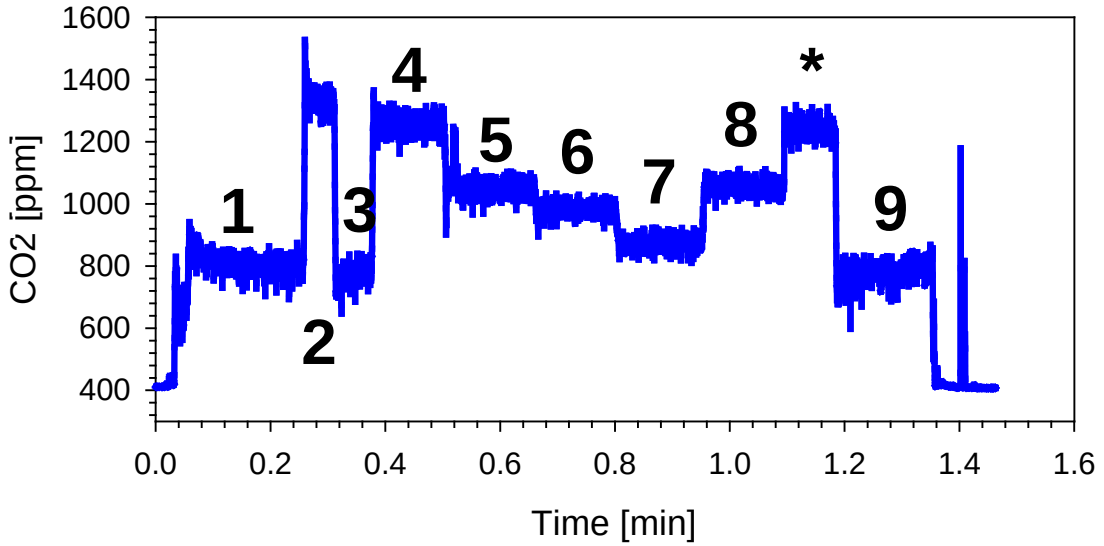
- The weather conditions in Jan 2018 were different from ECLIF (Sep 2015)
- Improved duration of stable power settings led to improved statistics despite non-ideal weather conditions

ND-MAX/ECLIF Test matrix

No.	N1 [%]	t [min]	
1	23	8	*Taxi*
2	82	3	*Climb*
3	23	3	*Taxi*
4	75	7	
5	60	8	
6	53	8	*Approach*
7	40	8	
8	60	8	
9	23	8	*Taxi*

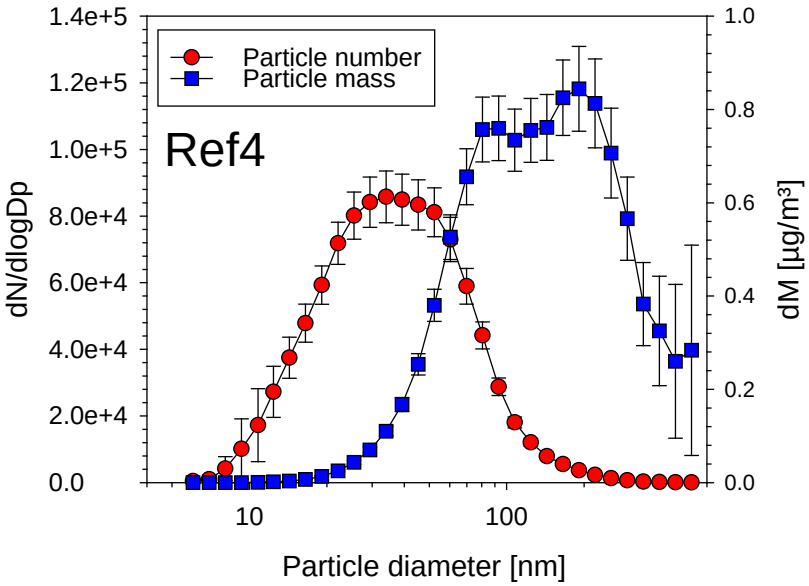
- 60 min test run for each fuel
- Comparison to LTO cycle settings via fuel flow

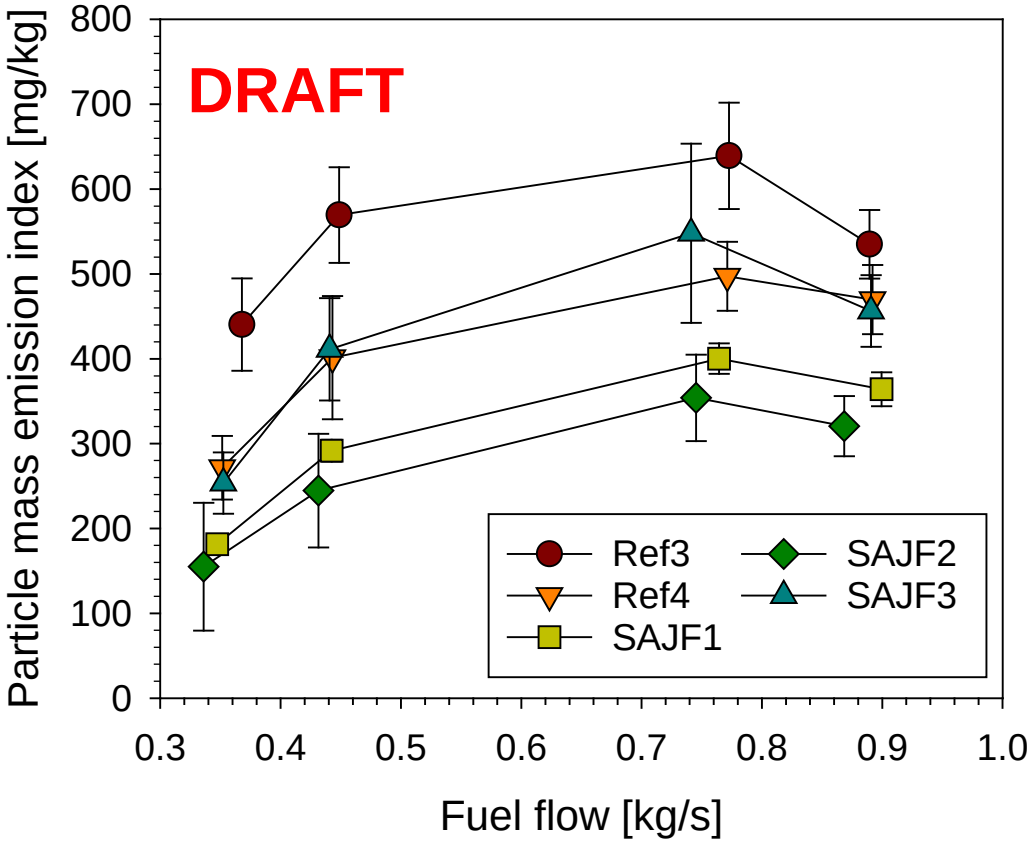




ND-MAX/ECLIF Emission indices

- The dependence of soot emission on fuel flow is similar to the previous campaign
- Particle size distribution shifted to larger particles than ECLIF part 1

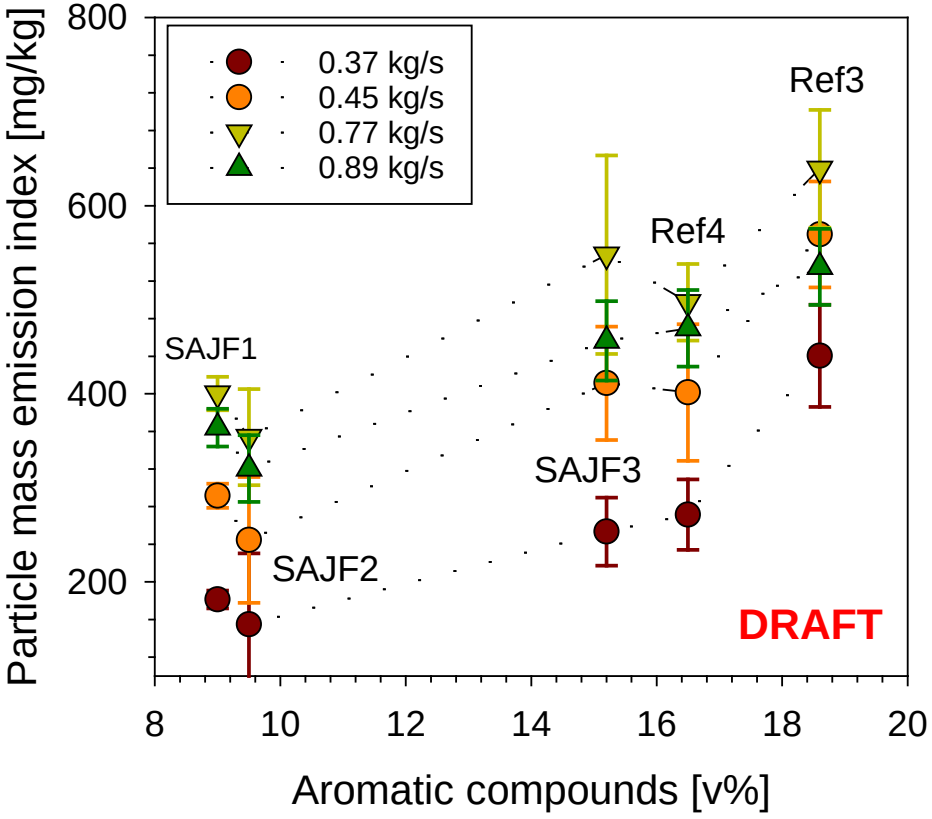


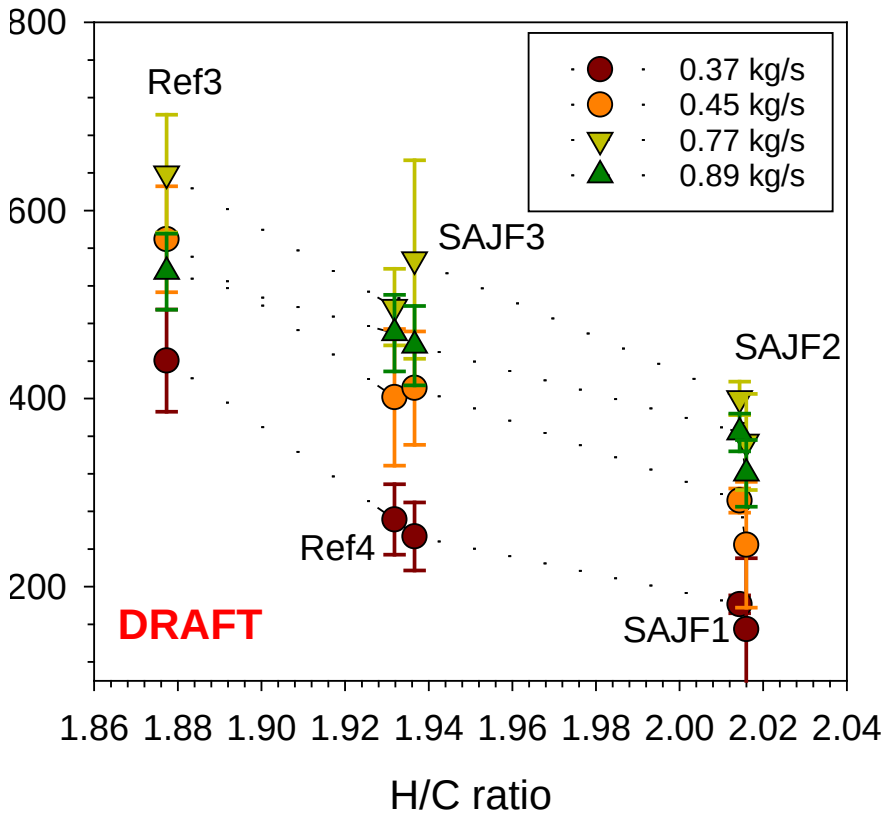


- The results of the different research groups are currently consolidated!

ND-MAX/ECLIF EIs – Aromatics vs. H/C ratio

- Trend in emission indices follows the observations in ECLIF part 1

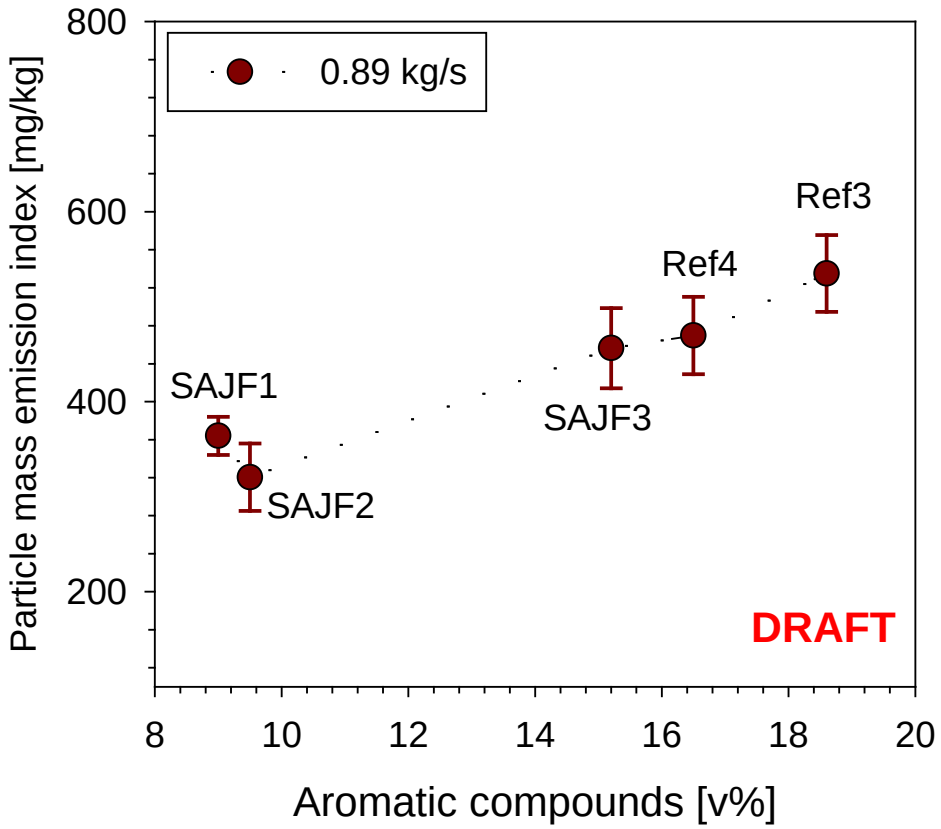


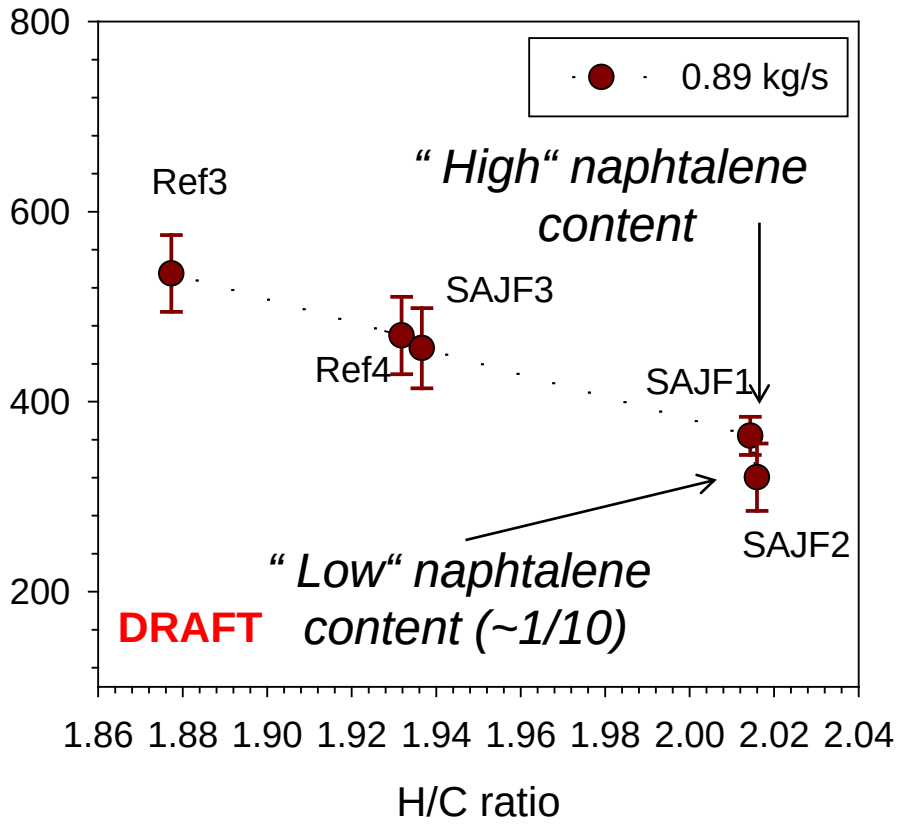


- The emission indices of SAJF3 are associated with higher uncertainties (weather conditions, non-ideal alignment); further analysis necessary

ND-MAX/ECLIF EIs – Aromatics vs. H/C ratio

- Highest power setting („climb“) provides insight into the dependencies





- Sub-component composition beyond aromatics is a relevant feature for future research

Conclusions & Outlook

- The data sets from both campaigns provide unique insight into the impact of alternative fuels on soot emission
- Reductions of soot emission in the range of 60-70 m% can be achieved by the described fuel blends
- The H/C ratio is a feasible indicator for jet engine soot emission; the details in chemical composition may result in small biases though
  - Relevant for future fuel design activities
  - Follow-up GCxGC analysis of ND-MAX/ECLIF fuels
- Combination with cloud data and atmospheric particle concentrations (contrail measurements) will allow quantifying the reduction potential under flight conditions (→ climate effects, particle/cloud interactions)

Thank you for you attention!

universität innsbruck

NASA

DLR

ECLIF/
ND-MAX
Ground
Measurement
Team

MISSOURI S&T

AERODYNE RESEARCH, Inc.

National Research Council Canada | Conseil national de recherches Canada

The ground team thanks Transport Canada for additional funding.

DLR