Characterisation and first measurements of a fully-automated mini-AMS on a passenger aircraft (IAGOS-CARIBIC)

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January 21, 2021, AMS User Meeting, C. Schulz
IAGOS-CARIBIC infrastructure

- IAGOS = In-service Aircraft for a Global Observing System
- European Research Infrastructure
- Part: IAGOS-CARIBIC
  - CARIBIC = Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container
  - Passenger aircraft with scientific measurement container
  - In-depth and complex investigation of UT/LS on regular basis

http://www.caribic-atmospheric.com/

<table>
<thead>
<tr>
<th>When</th>
<th>What</th>
</tr>
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<tbody>
<tr>
<td>October 2012</td>
<td>DFG proposal (TROPOS, MPIC, JGU Mainz)</td>
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<tr>
<td>January 2014</td>
<td>Delivery of miniAMS</td>
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<td>2014-2016</td>
<td>Reconfiguration, automatic operation, certification → Florian Rubach</td>
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<td>January 2017</td>
<td>First EMI-test at Lufthansa</td>
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<tr>
<td>March 2017</td>
<td>New DFG proposal (TROPOS)</td>
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<tr>
<td>February 2018</td>
<td>First flight – no data</td>
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<tr>
<td>October 2018</td>
<td>First flight with recorded data</td>
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<td>November 2018</td>
<td>Laboratory characterisation and comparison with HR-ToF-AMS at TROPOS → Anna Ludwig, Laurent Poulain</td>
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<tr>
<td>October 2018 – March 2020</td>
<td>38 flights, 14 successful with available data</td>
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<td>March 2020</td>
<td>Last IAGOS-CARIBIC flight so far</td>
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<tr>
<td>Ongoing until Dec 2021</td>
<td>Modification and new certification for Lufthansa A350</td>
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</tbody>
</table>
Technical challenges for full automation

- No operator on board
- No connection to instrument
- 1 flight series = 4 flights
  → Full automation needed!

Schneider et al., in prep. for AMT
Technical challenges for full automation
Technical challenges for full automation

Master PC

Initialize

Standby

Measure

Instruments

CARIBIC-AMS PC

VBus Unit

Pre-pump

Turbomolecular Pump

Valve 1

Valve 2

Valve 3

Inlet

Filter

Constant Pressure Inlet

CPI

Particle beam

Filament

Vaporizer

P1

P2

Chopper

Aerodynamic lens

Ion path

Signal

MCP

Constant Pressure Inlet

Initialize minimal power consumption

Standby default

Measure \( p_{amb} < 800 \text{ mbar} \)
Technical challenges for full automation

Initialize:
- VBus unit and PC on
- CARIBIC-MAN software starts
- Everything handled by CARIBIC-MAN and VBus unit

Master PC

Initialize: minimal power consumption

Standby Measure

Instruments

CARIBIC-AMS PC

VBus Unit

- Constant Pressure Inlet
- Initialize: minimal power consumption
- Standby default
- Measure
- Initialize:
  - VBus unit and PC on
  - CARIBIC-MAN software starts
  - Everything handled by CARIBIC-MAN and VBus unit

Pre-pump

Valve 1

Turbomolecular Pump

Valve 2

Particle beam

Valve 3

Constant Pressure Inlet

Aerodynamic lens

Chopper

Filament

Vaporizer

P1

P2

P3

MCP

Ion path

Signal
Technical challenges for full automation

**Standby:**
- Pre-pump on, valve 1 open

**Standby:**
- Minimal power consumption
- $p_{amb} > 800$ mbar

**Measure**

**Instruments**

**CARIBIC-AMS PC**

**VBus Unit**

- Master PC
- Pre-pump
- Turbomolecular Pump
- Filament
- Vaporizer

**Inlet**

**Valve 1**

**Valve 2**

**Valve 3**

**Filter**

**P1**

**P2**

**P3**

**Chopper**

**Particle beam**

**Aerodynamic lens**

**Ion path**

**Signal**

**MCP**

**Constant Pressure Inlet**

**Standby:**
- Pre-pump on, valve 1 open

**Measure**

**Initialize**

**Master PC**

**Instruments**
Technical challenges for full automation

**Standby:**
- Pre-pump on, valve 1 open
- Turbopump on

**Initialize** minimal power consumption $p_{amb} > 800$ mbar

**Measure**

**Instruments**

CARIBIC-AMS PC

VBUS Unit

Master PC

- Pre-pump
- Valve 1
- Turbopump on

**Inlet**

- Filter
- Valve 3

- Pre-pump

- Valve 1

- Constant Pressure Inlet
- Valve 2

- Turbomolecular Pump

- Particle beam
- Chopper
- Filament
- Vaporizer

- Ion path

- Signal
- MCP

- P3

- $< 5$ mbar
Technical challenges for full automation

**Standby:**
- Pre-pump on, valve 1 open
- Turbopump on
- TPS on, DAQ starts

**Standby**

- Power consumption $p_{amb} > 800$ mbar

**Master PC**

**Initialize**

**Measure**

**VBus Unit**

**CARIBIC-AMS PC**

**Instruments**

**Pre-pump**

**Valve 1**

**Valve 3**

**Valve 2**

**Filter**

**Inlet**

**Turbomolecular Pump**

**Particle beam**

**Filament**

**Vaporizer**

**P1**

**P2**

**P3**

**Signal**

**MCP**

**Chopper**

**Constant Pressure Inlet**

**Aerodynamic lens**

**Ion path**
Technical challenges for full automation

Measure:
• Valve 2 (inlet) open, CPI on
• Filament, vaporizer, MCP on

Master PC

Initialize minimal power consumption
Standby $p_{amb} > 800$ mbar
Measure $p_{amb} < 800$ mbar

Instruments

CPI: Molleker et al., 2020
Technical challenges for full automation

**Measure:**
- Valve 2 (inlet) open, CPI on
- Filament, vaporizer, MCP on
- m/z & SI calibration
- Data acquisition (ambient & filter)

- **Initialize** minimal power consumption
- **Standby** $p_{\text{amb}} > 800 \text{ mbar}$
- **Measure** $p_{\text{amb}} < 800 \text{ mbar}$

**Instruments**

**CARIBIC-AMS PC**

**VBus Unit**

**Master PC**

**Pre-pump**

**Turbomolecular Pump**

**Particle beam**

**Chopper**

**Ion path**

**Signal**

**Filament**

**Vaporizer**

**Valve 1**

**Valve 2**

**Valve 3**

**Constant Pressure Inlet**

**Aerodynamic lens**

**P1**

**P2**

**P3**

**Filter**

**< 3 e-6 mbar**
Technical challenges for full automation

**Standby:**
- Valve 2 (inlet) closed
- DAQ stops
- Voltages off

**Master PC**

Initialize minimal power consumption

**Standby**

\[ p_{\text{amb}} > 800 \text{ mbar} \]

Measure \[ p_{\text{amb}} < 800 \text{ mbar} \]

**Instruments**

**CARIBIC-AMS PC**

**VBus Unit**

**Pre-pump**

**Turbomolecular Pump**

**Valve 1**

**Valve 2**

**Valve 3**

**Filter**

**Constant Pressure Inlet**

**Aerodynamic Lens**

**Chopper**

**Particle beam**

**Filament**

**Vaporize**

**Signal**

**Ion path**

**< 3 e-6 mbar**

**Valve 2 (inlet) closed**
Technical challenges for full automation

Power off

Master PC

Initialize

minimal power consumption

Standby

p_{amb} > 800 \text{ mbar}

Measure

p_{amb} < 800 \text{ mbar}

Instruments

CARIBIC-AMS PC

VBus Unit

Pre-pump

Turbomolecular Pump

Valve 1

Valve 2

Valve 3

Filter

Constant Pressure Inlet

Aerodynamic lens

Particle beam

Chopper

Filament

Vaporizer

P1

P2

P3

Ion path

Signal

MCP

C. Schulz, AMS User Meeting 2021
Comparison measurements

- AMS calibrated with CPC
- Comparison with HR-ToF-AMS
  - Very good agreement between CARIBIC-AMS and HR-ToF-AMS

Measurements by Anna Ludwig and Laurent Poulain
Schneider et al., in prep. for AMT
Comparison measurements

- Comparison with C-ToF-AMS
- Very good agreement for different species

Measurements by Johannes Schneider and Christiane Schulz
Schneider et al., in prep. for AMT
ePToF-Chopper

- MPIC-internal developed automation
  → Electronics workshop, Christian Gurk
- Sequence length: 127
- Oversample: 6; standard value is 2?
  (https://sites.google.com/site/tofamsdaq/manual-v5/menu-window/configuring-eptof)
ePToF-Chopper

- MPIC-internal developed automation → Electronics workshop, Christian Gurk
- Sequence length: 127
- Oversample: 6; standard value is 2? (https://sites.google.com/site/tofamsdaq/manual-v5/menu-window/configuring-eptof)

- Microprocessor with frequency and phase automated rotating field
- Feedback of microprocessor via optical scanning of rotation
- Microprocessor gets pulse from chopper once per rotation

- Microprocessor generates a virtual „slit“-signal which is in phase with extraction pulses generated from MS (every 762 = 127 * 6) → triggering of data acquisition; efficiency > 95%
  - Issue: if the virtual slit signal is not in phase with extraction pulse, some complete chopper rotations will not be used for measurements → efficiency below 50%
  - Real phase of chopper adjusted relative to virtual slit pulses

Besides: maintenance checks if chopper wheel does not hit the wall, servo is not consuming to much power
• No pressure dependence
• CPI provides constant mass flow and pressure in aerodynamic lens
Data availability

- October 2018 – March 2020 → 38 flights
- 14 successful with (partly) available data
Case Study: Alberta forest fire plume, June 2019

- FL570: Munich – Vancouver
- June 2019: forest fires in Canada for several days
- Plume visible by satellite

Schulz et al., EAC, 2020
Case Study: Alberta forest fire plume, June 2019

- FL570: Munich – Vancouver
- June 2019: forest fires in Canada for several days
- Plume visible by satellite

https://wvs.earthdata.nasa.gov/api/v1/snapshot?REQUEST=GetSnapshot&TIME=2019-06-19T00:00:00Z&BBOX=34.9734375,-138.0375,73.153125,-63.857812499999994&CRS=EPSG:4326&LAYERS=MODIS_Terra_CorrectedReflectance_TrueColor,Coastlines,MODIS_Combined_Thermal_Anomalies_All&WRAP=day,x,none&FORMAT=image/png&WIDTH=1688&HEIGHT=869&ts=1597405116941

Schulz et al., EAC, 2020
Low values for most part of the flight
One massive plume event

Case Study: Alberta forest fire plume, June 2019

Altitude

CO

rBC

Aerosol mass / μg m⁻³

1000
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000

Time / UTC
18:00 19:00 20:00 21:00 22:00 23:00

FL 570

Schulz et al., EAC, 2020
Case Study: Alberta forest fire plume, June 2019

- Low values for most part of the flight
- One massive plume event
- CO -> 1200 ppb
- rBC -> 2 µg m\(^{-3}\)
- Org, NO\(_3\), NH\(_4\) ↑
- Aerosol mass conc. (sum) -> 220 µg m\(^{-3}\)

Schulz et al., EAC, 2020
Organic aerosol from forest fires not strongly oxidized, but partly processed.
Lens pressure measurements

- Ongoing laboratory measurements
- Lens transmission not ideal
- Idea: lens pressure too low
Lens pressure measurements

- Ongoing laboratory measurements
- Lens transmission not ideal
- Idea: lens pressure too low
- Issue: increasing $p_{\text{lens}}$ not possible → turbo pump power consumption close to maximum

250nm: not corrected for doubly charged particles

$P_{\text{amb}} = 200\text{ mbar}$
$\text{NH}_4\text{NO}_3$
flow corrected
△ 11.12.2020
● 17.01.2021

$1.7\text{ mbar} = 1.275\text{ Torr}$

$1.7\text{ mbar} = 1.9\text{ Torr}$

C-ToF-AMS:
$p_{\text{lens}} = 2.5\text{ mbar}$
$= 1.9\text{ Torr}$

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**Lens pressure measurements**

- Ongoing laboratory measurements
- Lens transmission not ideal
- Idea: lens pressure too low
- Issue: increasing $p_{\text{lens}}$ not possible $\rightarrow$ turbo pump power consumption close to maximum

- Lens pressure is too low
  - Lens transmission not ideal at the moment $\rightarrow$ what to do?
  - Turbo split flow pump close to maximum $\rightarrow$ no increase of $p_{\text{lens}}$ possible
  - Skimmer maybe too small $\rightarrow$ need to check, any information on this available?
  - What lens pressure do other miniAMS-users have?

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**Graph Details**

- $P_{\text{amb}} = 200$ mbar
- NH$_4$NO$_3$
- Flow corrected
- $1.7$ mbar = 1.275 Torr
- Plateau?
- $p_{\text{lens}} = 2.5$ mbar = 1.9 Torr

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250nm: issue with doubly charged particles
Thank you for your attention!

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