Performance of the new continuous carbonaceous aerosol measurement system FATCAT during long term unattended measurement campaigns

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Funding: Global Atmosphere Watch (GAW) Science Projects, Switzerland. Federal Office of Meteorology and Climatology, MeteoSwiss
GAW-CH Science Projects 2018-2021
**Importance of carbonaceous aerosol**

World Meteorological Organization / Global Atmosphere Watch (GAW) aerosol measurement recommendations (2003 and 2016):

- “Carbonaceous species are the least understood and most difficult to characterize of all aerosol chemical components.”
- “It is recommended that [total carbon] TC, [organic carbon] OC and [elemental carbon] EC be measured in the GAW programme.”

**Biggest limitation:** There is no reliable field measurement device for EC/OC analysis. These measurements are offline, scarce, and have a time resolution of one day. A simple and robust method is urgently needed.

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FAst Thermal CArbon Totalizer (FATCAT)

1. Capture particles on a filter
2. Flash-heat up the filter to ~800°C (< 1 minute)
3. Catalytic converter
4. CO2 detection (NDIR)

- **Unique:** Rigid metal filter (no filter displacements or leaks)
- **Unique:** Direct and homogeneous heating of the filter (instead of using a heating filament or a furnace)
- **Unique:** Calibration performed using CO₂ (other devices use a sugar solution) and through calibration of a mass flow controller
- **Most precise instrument:** Limit of detection LoD=0.1 µg-C

Not restricted to ambient concentrations. Also works for emission measurements.
Our route during the GAW-CH Science Projects 2018-2021

Tested at diverse sites:
1) Urban roadside (Zurich)
2) Urban background (Windisch)
3) Regional background (Payerne)
4) Above the planetary boundary layer (Jungfraujoch; 3500 m.a.s.l.)

Key specifications

- Limit of detection: 0.1 μg of carbon (μg-C)
- Dynamic range: > 10^3 μg-C
- Sampling flowrate: ≤ 0.6 m³/hour (0.36 m³/hour at the JFJ)

The low limit of detection (LoD) makes our device the most precise total carbon measuring system currently available. For ambient samples, this LoD translates to concentrations of 0.08 μg-C/m³ and 0.16 μg-C/m³ for a time resolution of two and one hours, respectively.

For the JFJ site LoD= 0.14 μg-C/m³ with two hours time resolution.
Jungfraujoch, Sphinx Observatory

Black Carbon (µg/m$^3$)
Total Carbon (µg/m$^3$)

BC data provided by PSI Switzerland
Unique fast thermograms
Identification of source fingerprints

Jungfraujoch, Sphinx Observatory

BTC data provided by PSI Switzerland

Biomass
Fossil Fuel

Organic Carbon
(Background?)

BC data provided by PSI Switzerland

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Unique fast thermograms
Identification of source fingerprints

Jungfraujoch, Sphinx Observatory

Total Carbon (µg/m³)

Black Carbon (µg/m³)

Originating from California Wildfires

BC data provided by PSI Switzerland
Comparing Ambient Thermograms

Local fossil fuel?

Biomass?

Wide components

Narrow

Overlapping
Does filter load affects wide or position of the components?

- Laboratory samples do not suggest that loading influences the shape or position of the components (filter loads comparable or higher than ambient samples).
- Diversity and volatility of the species determine the shape and position of the components (needs experimental conformation).
- Four components fit is purely pragmatic based on data from Zurich and JFJ.

AeroTox Campaign, 29.09.2020 - MiniCAST, uncoated to high coating

- EMPIR 18HLT02 AeroTox project: http://empir.npl.co.uk/aerotox/
Maintenance required so far:

- **Sampling Filter**: First filter replacement after one year of continuous operation. The new filter should be longer-lived: no signs of degradation after more than one year of operation.

- **Flash furnace**: Failure at a soldering point on the printed circuit board (PCB) after one year of operation. We have identified the weak spot. This will be solved in the next board generation.

- **Calibration**: NDIR CO2 sensor has been calibrated once a year. We have timed this with the above-mentioned maintenance. (NDIR drift is not a problem, the signal needs to stable only for two minutes during the analysis cycle)

- **Analysis gas**: New gas bottle of synthetic air (50L at 200 bar) required every 4 months during the Jungfraujoch campaign (two-hour time resolution).

- **Data communication**: Approximately once per month, very minor logfile error (½ second of data is lost). Software optimization is required.
What comes next?

• Further optimization of the hardware?
  – Larger filter for higher collection flow or dual-head version
  – Geometry changes (e.g. 19" rack version)
  – Internal flow optimization (better thermogram resolution)
  – CO2 calibration control or automatic recalibration

• Specialized measurement campaigns?
  – Together with other novel instruments (e.g., photothermal interferometer, ACSM, or Aerosol's TCA)
  – Potential aerosol measurements (SOA potential using an oxidation flow reactor)
  – Further measurements at other locations (we are open to collaborations)

• Interpretation of data/thermograms?

• Other suggestions?
Acknowledgements

Switzerland. Federal Office of Meteorology and Climatology, MeteoSwiss

Swiss Federal Office for the Environment

Empa
Materials Science and Technology

Stadt Zürich
Gesundheits- und Umweltdepartement
Environmental and Health Protection Zurich
(Umwelt- und Gesundheitsschutz Zürich, UGZ)
Simultaneous measurement of ambient data with two units @ Windisch (Spring 2020)

- Comparison shows excellent linearity
- Data includes sample intervals of 1, 2 and 4 hours, as well as zero measurements.
- Synthetic aerosol generated by means of a CAST (Jing, ag) diffusion flame generator.

**Temperature measured behind sampling filter. Actual filter temperature is higher.**