University of Applied Sciences and Arts Northwestern Switzerland
School of Engineering

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

GAW

Schweizerische Eidgenossenschaft
Confédération suisse
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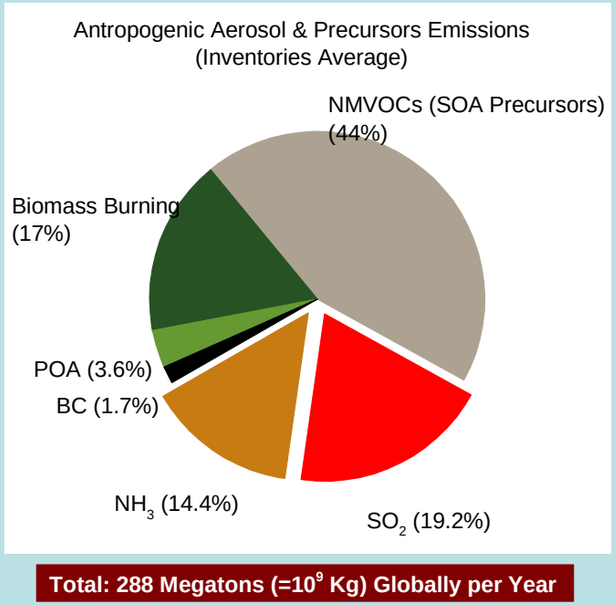
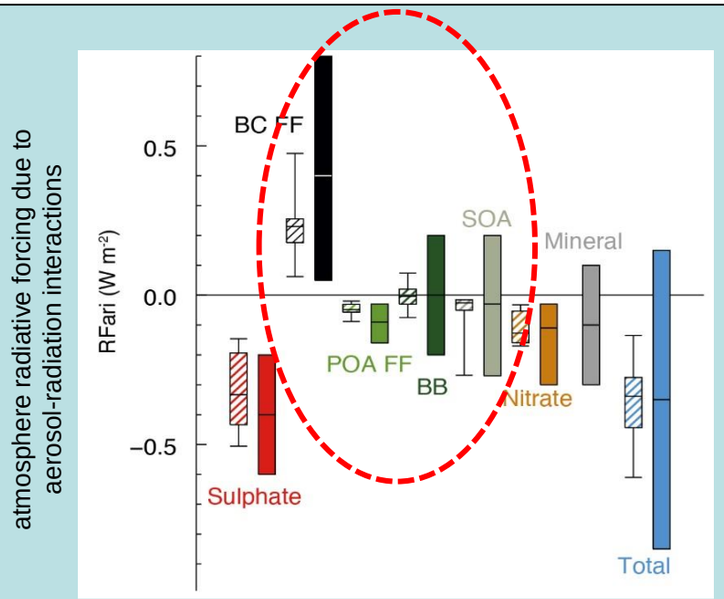
Importance of carbonaceous aerosol



Total: 288 Megatons (=10^9 Kg) Globally per Year



IPCC, 2013: 5th Assessment Report (AR5)

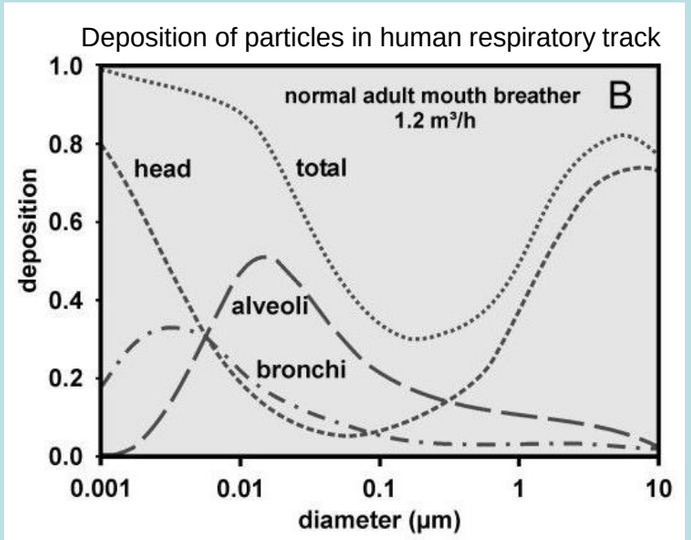


Figure: Geiser & Kreyling, 2010

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

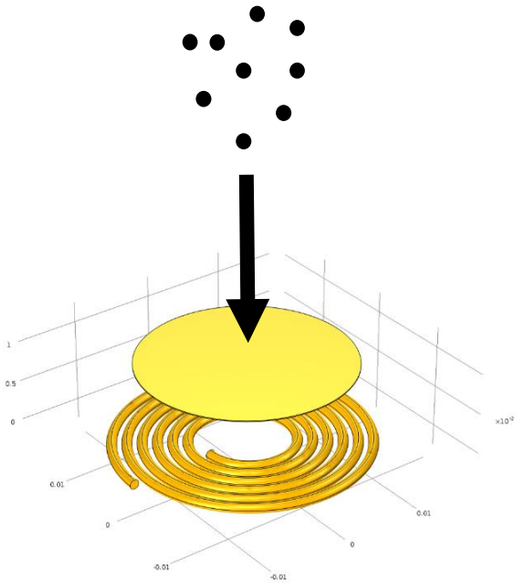
- "Carbonaceous species are the least understood and most difficult to characterize of all aerosol chemical components."
- "It is recommended that [total carbon] TC, [organic carbon] OC and [elemental carbon] EC be measured in the GAW programme"

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.

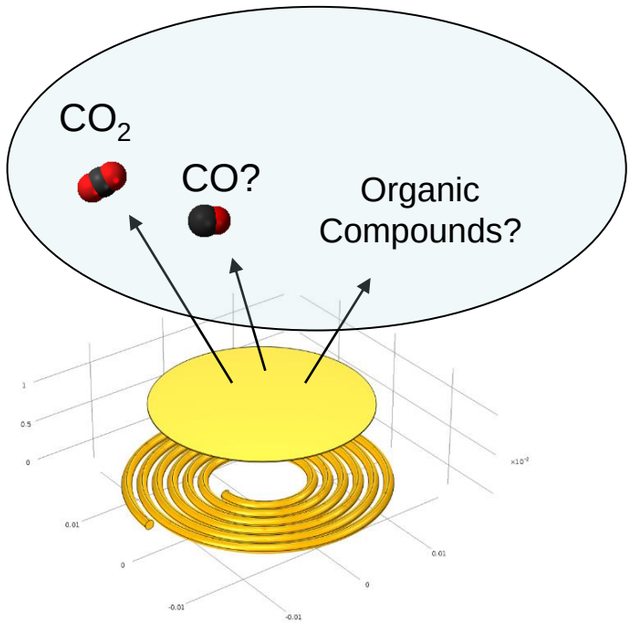
A simple and robust method is urgently needed.

FAst Thermal CArbon Totalizer (FATCAT)

- **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 CO_2 (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

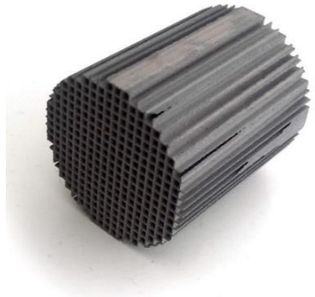


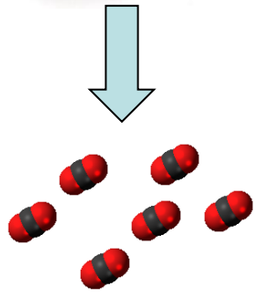
1. Capture particles on a filter



2. Flash-heat up the filter to ~800°C (< 1 minute)

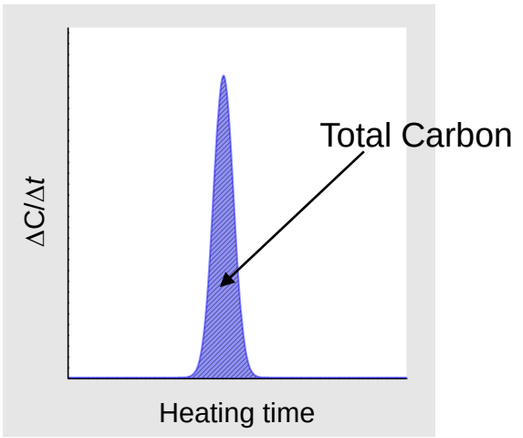
3. Catalytic converter



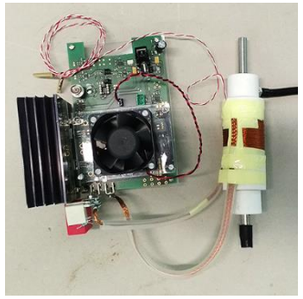


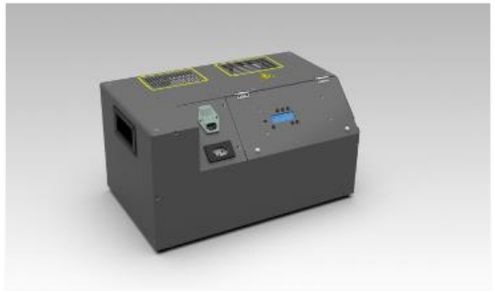
4. CO2 detection (NDIR)

Not restricted to ambient concentrations. Also works for emission measurements.



Our route during the GAW-CH Science Projects 2018-2021





Key specifications

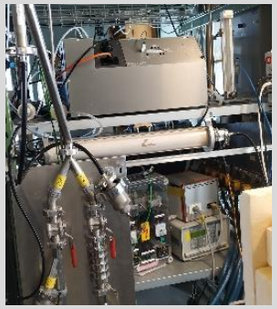
- Limit of detection: 0.1 µg of carbon (µg-C)
- Dynamic range: > 10^3 µg-C
- Sampling flowrate: ≤ 0.6 m^3/hour (0.36 m^3/hour at the JFJ)

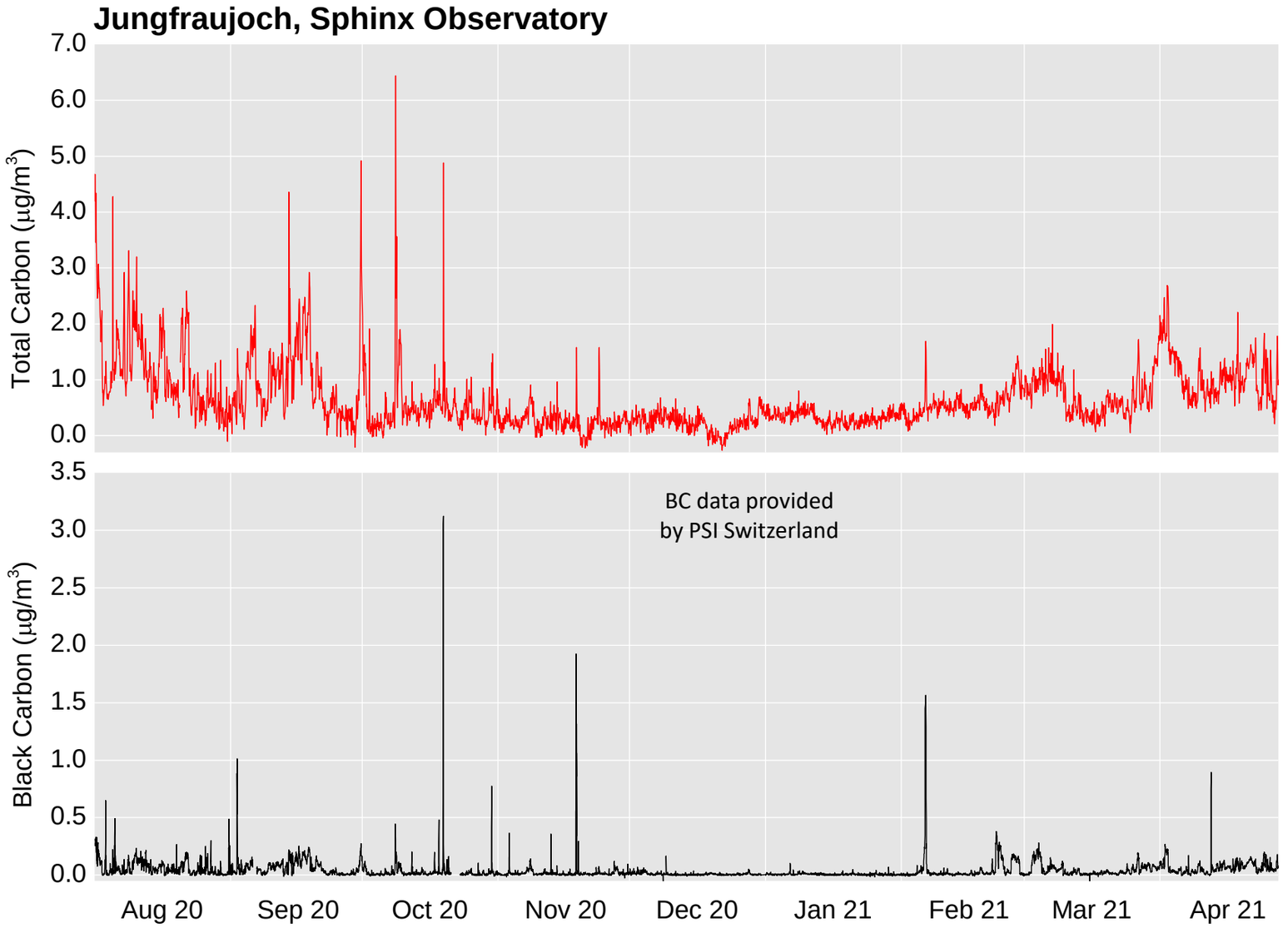
The low limit of detection (LoD) makes our device **the most precise total carbon measuring system currently available**. For ambient samples, this LoD translates to concentrations of 0.08 µg-C/m^3 and 0.16 µg-C /m^3 for a time resolution of two and one hours, respectively.

For the JFJ site LoD= 0.14 µg-C/m^3 with two hours time resolution.

Tested at diverse sites:

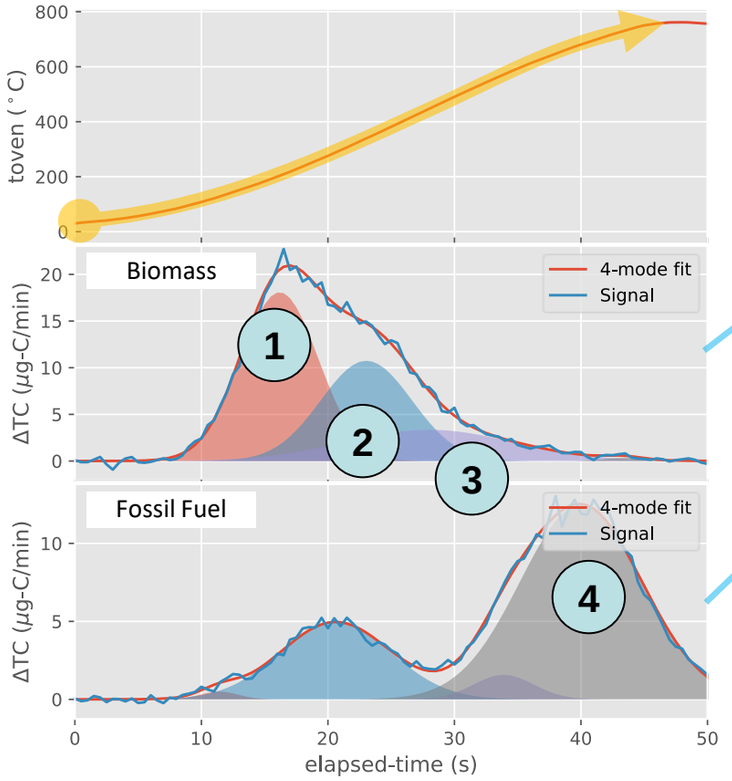
1) Urban roadside (Zurich)
2) Urban background (Windisch)
3) Regional background (Payerne)
4) Above the planetary boundary layer (Jungfraujoch; 3500 m.a.s.l.)



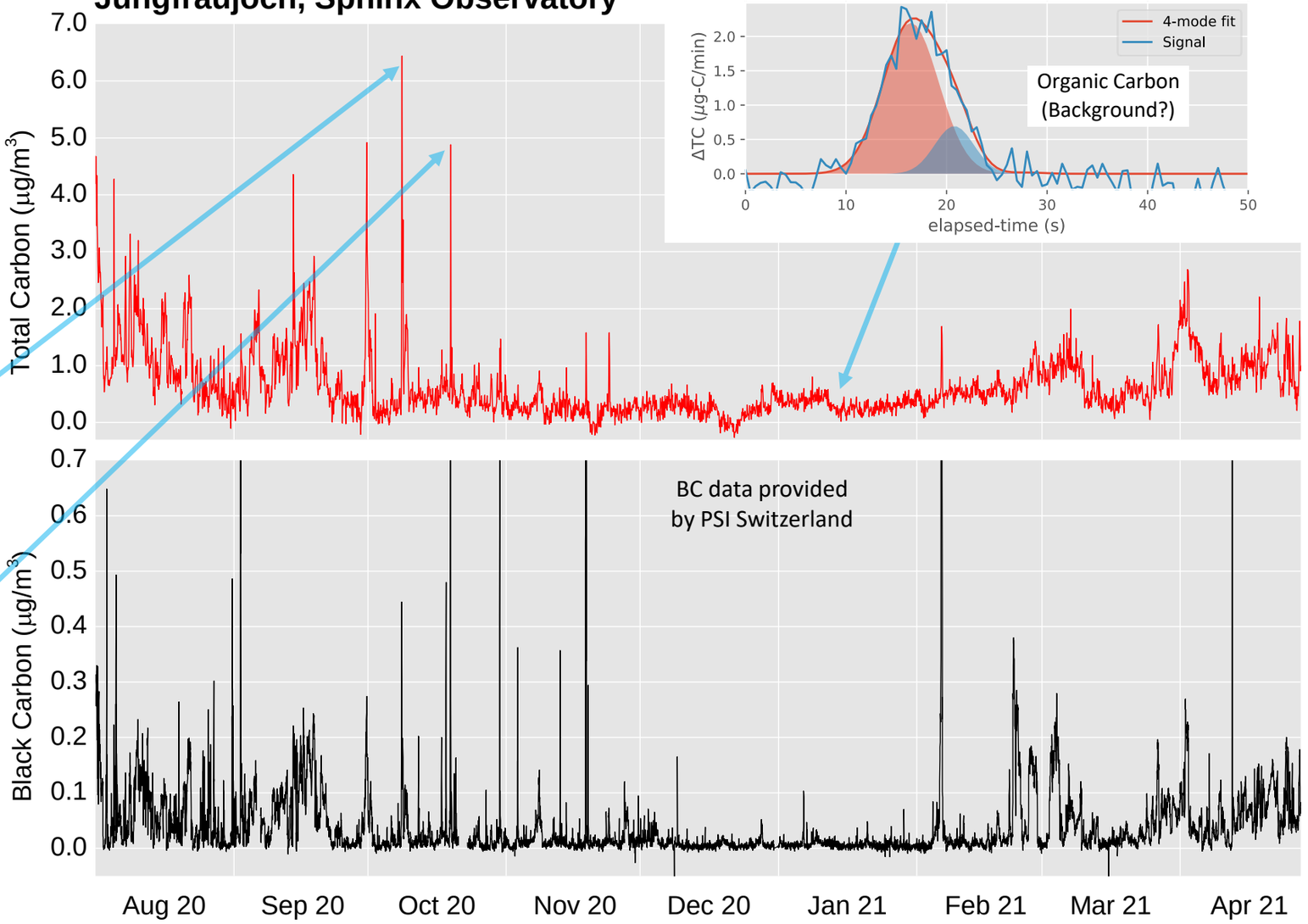

Jungfraujoch, Sphinx Observatory
Total Carbon (µg/m3)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Black Carbon (µg/m3)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
BC data provided
by PSI Switzerland
Aug 20
Sep 20
Oct 20
Nov 20
Dec 20
Jan 21
Feb 21
Mar 21
Apr 21

Unique fast thermograms

Identification of source fingerprints

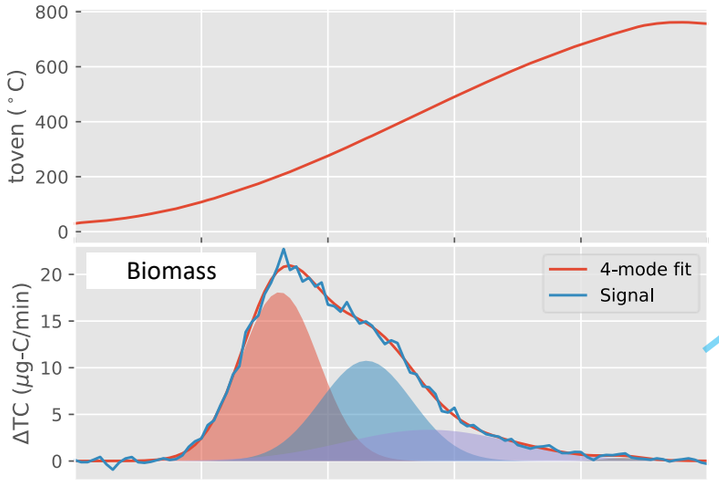


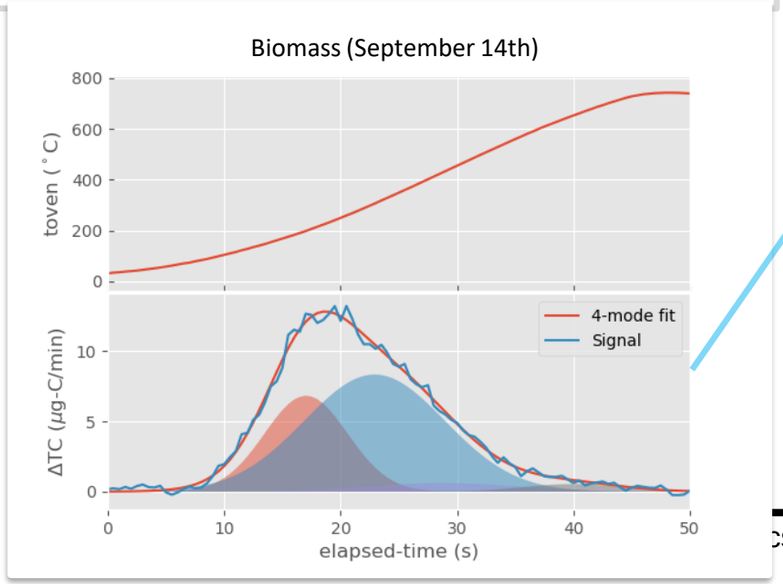
Jungfraujoch, Sphinx Observatory

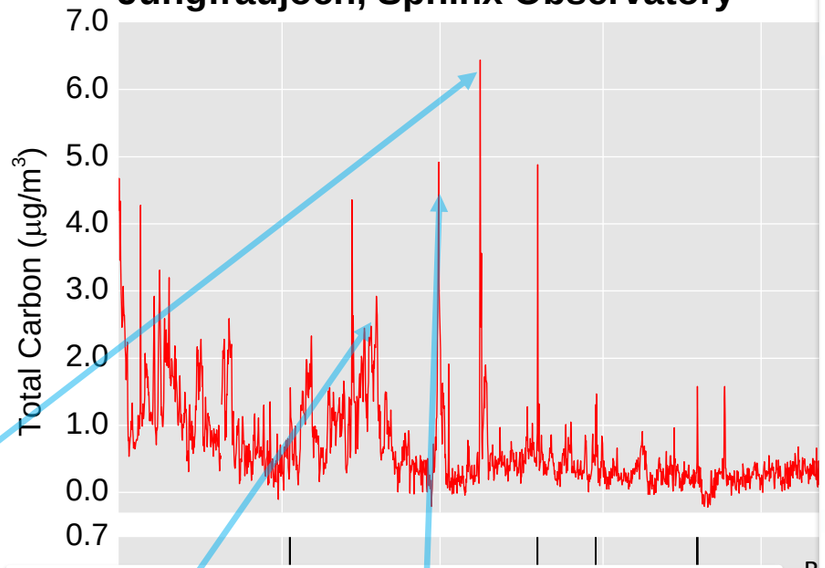


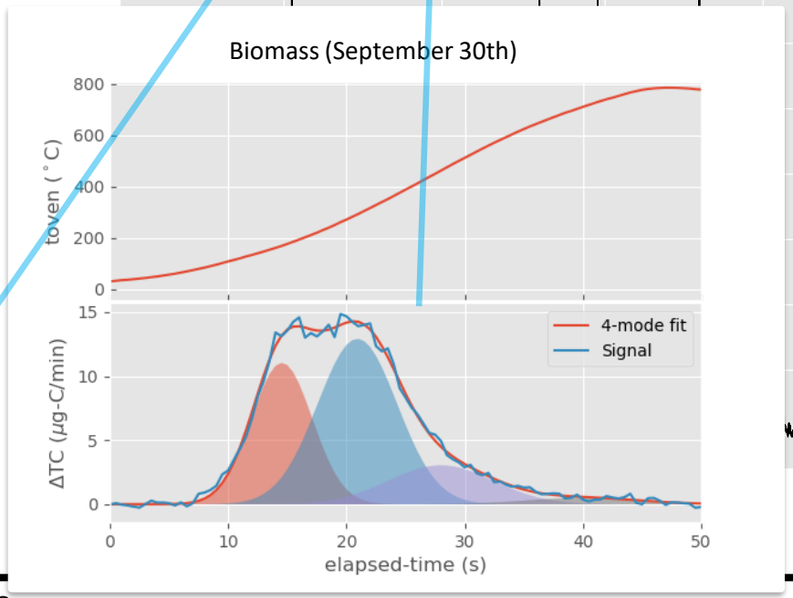
Unique fast thermograms

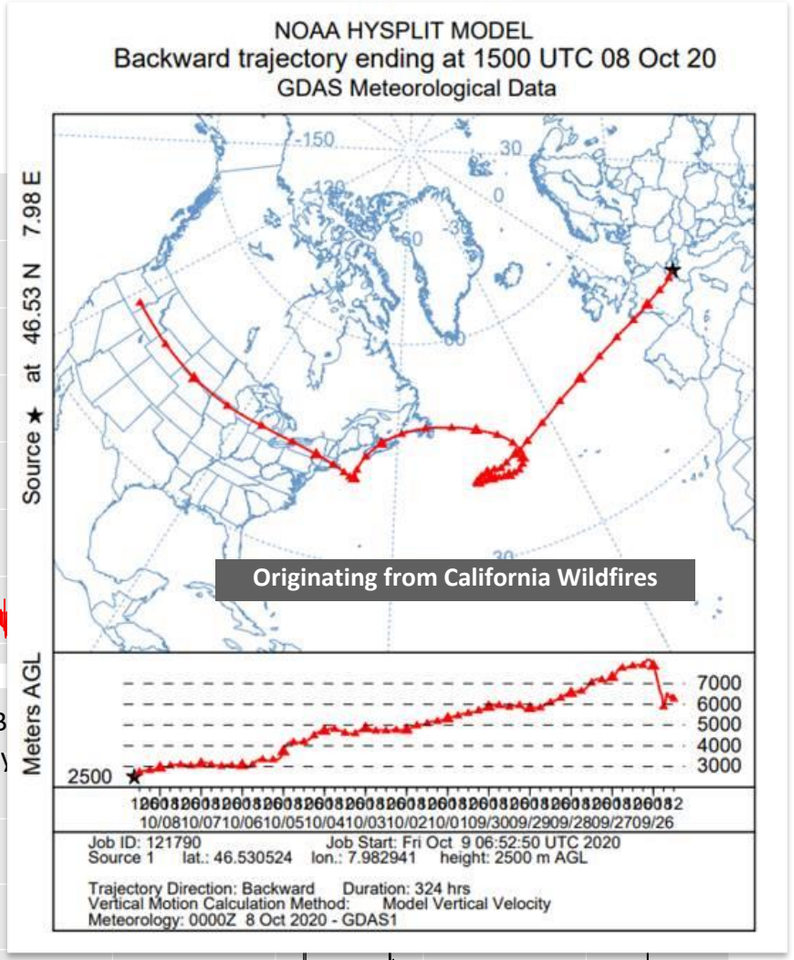
Identification of source fingerprints

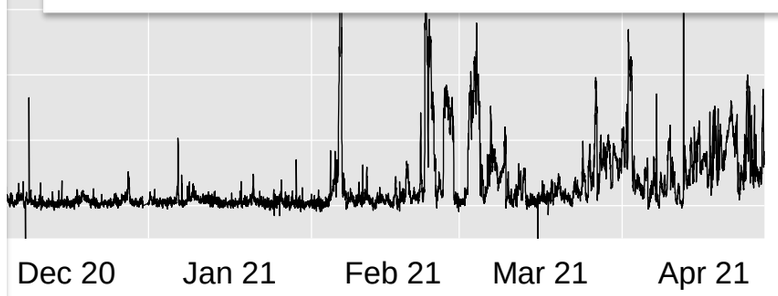






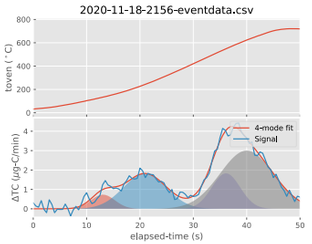


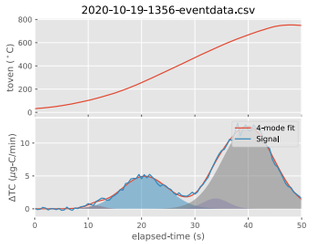


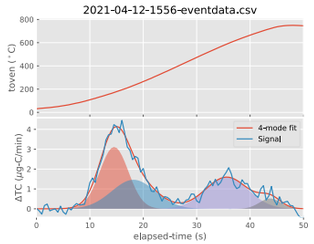


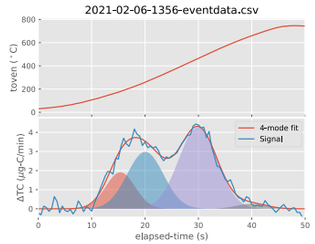
Comparing Ambient Thermograms

Local fossil fuel?

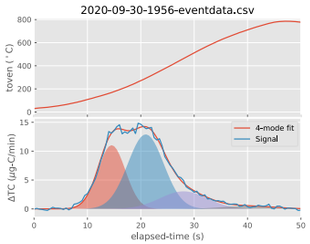


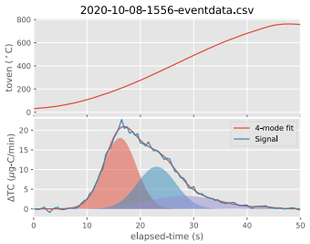


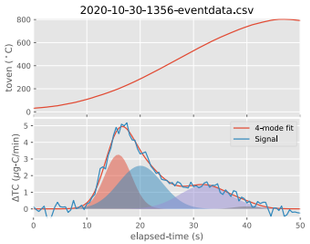


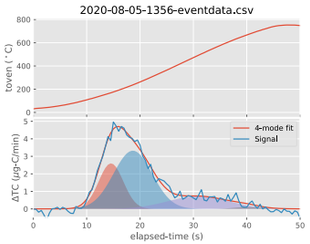


Biomass?

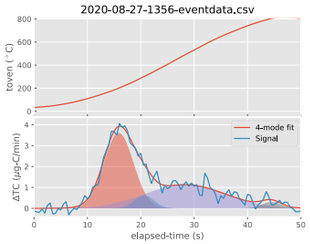




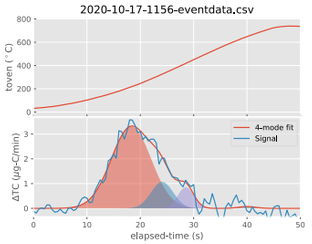




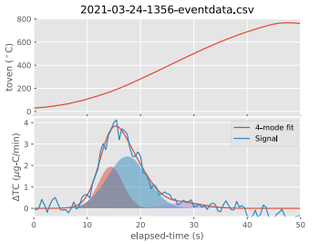
Wide components



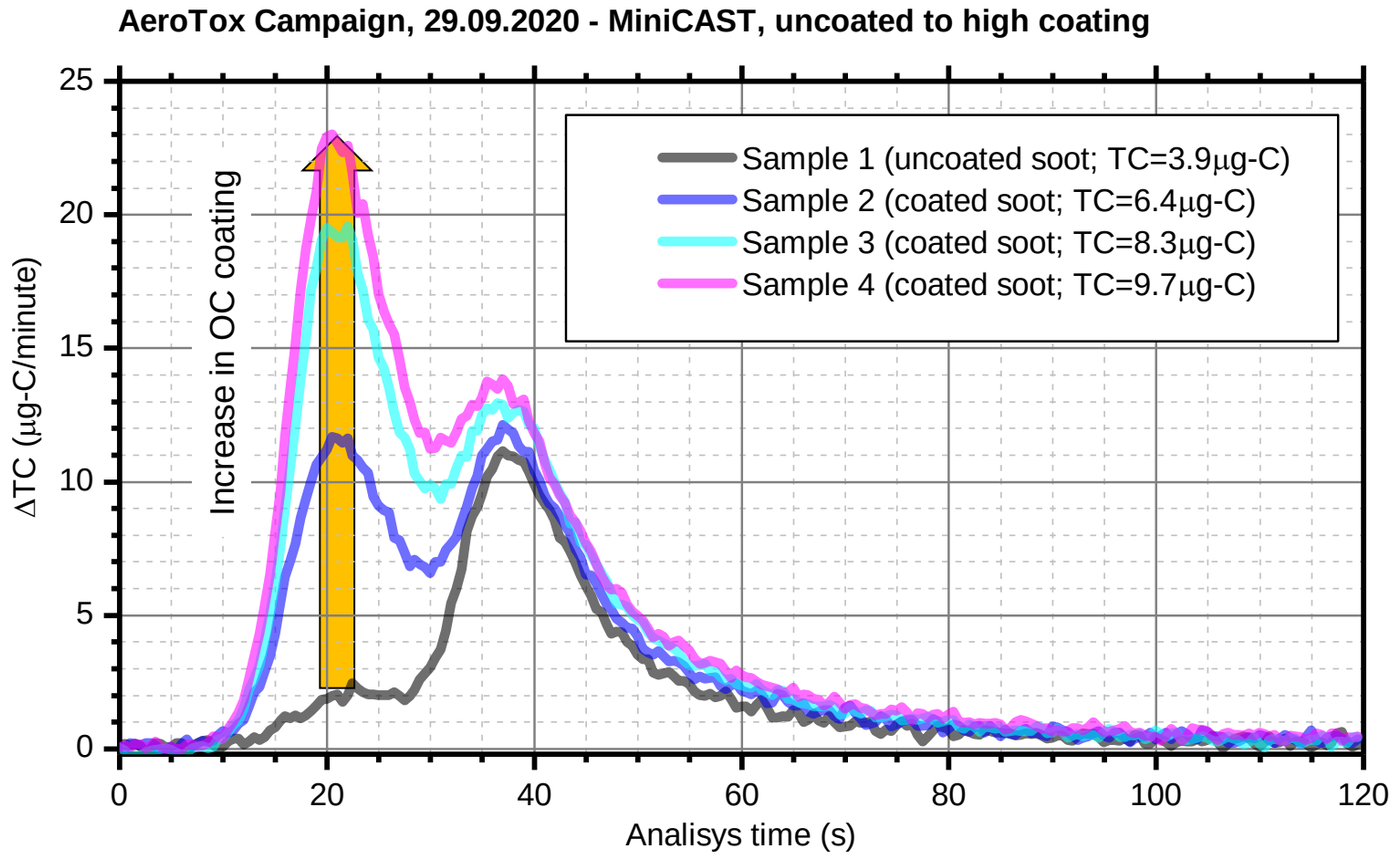
Narrow



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.

- 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

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Switzerland. Federal Office of Meteorology and Climatology, MeteoSwiss

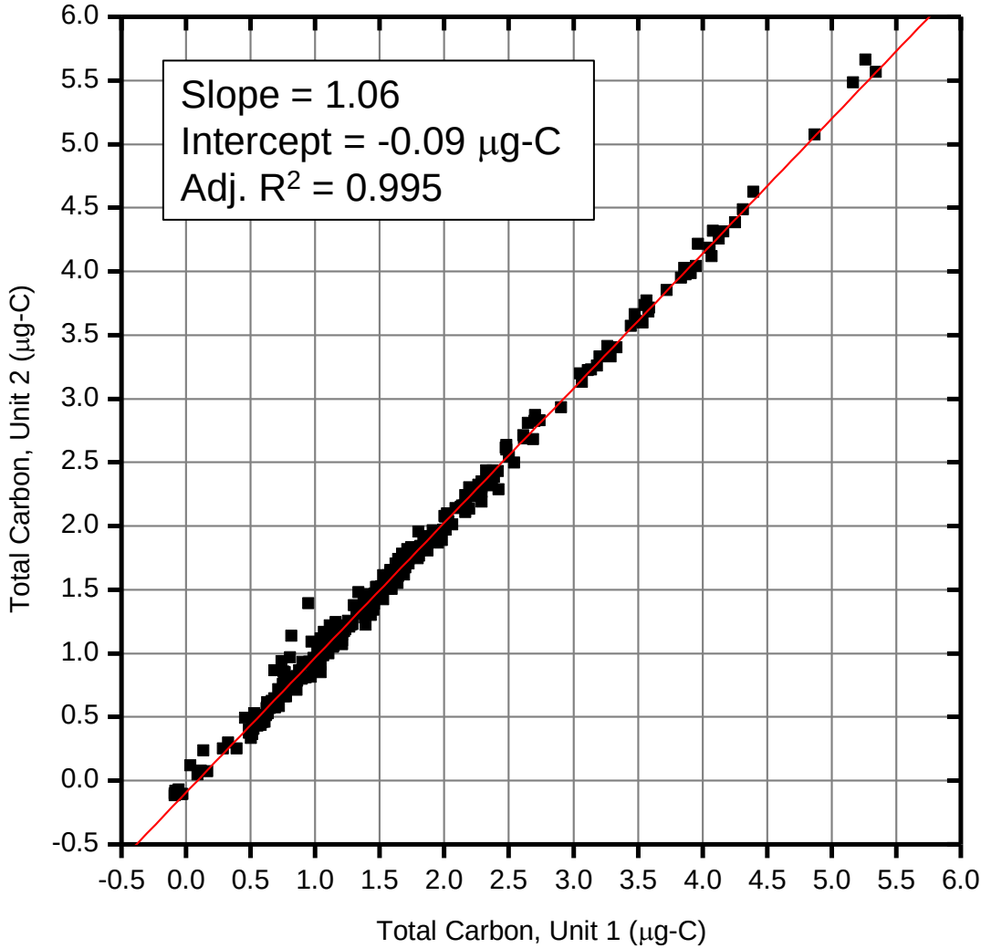
Swiss Federal Office for the Environment

Empa
Materials Science and Technology

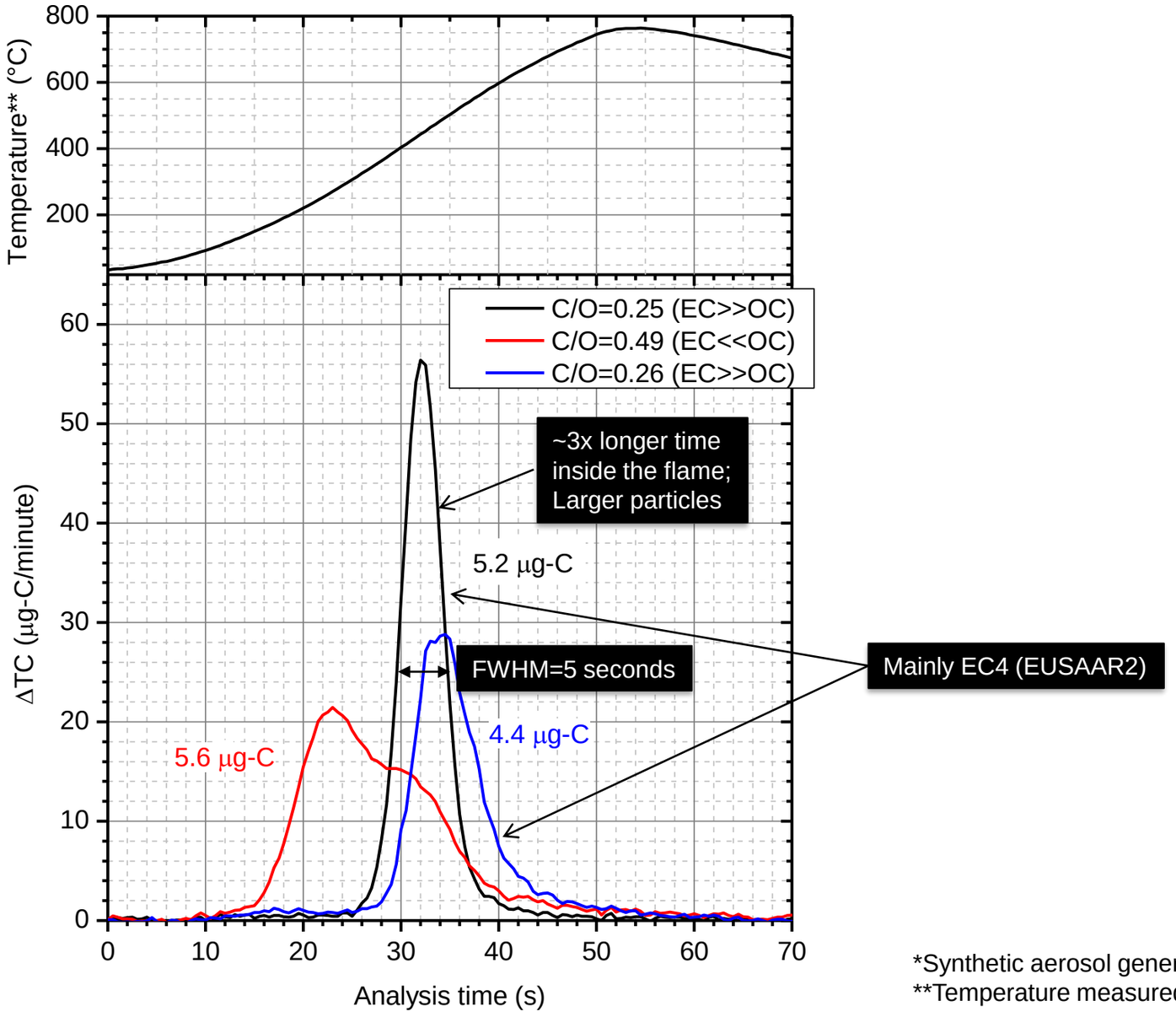
PAUL SCHERRER INSTITUT
PSI

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 excelent linearity
- Data includes sample intervals of 1, 2 and 4 hours, as well as zero mesurements.



*Synthetic aerosol generated by means of a CAST (Jing, ag) diffusion flame generator.
**Temperature measured behind sampling filter. Actual filter temperature is higher.