University of Applied Sciences and Arts Northwestern Switzerland
School of Engineering

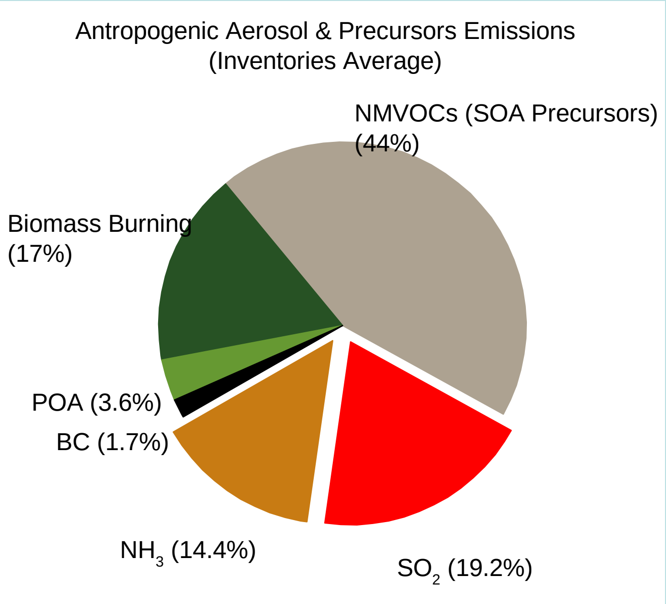
member of swissuniversities

FATCAT

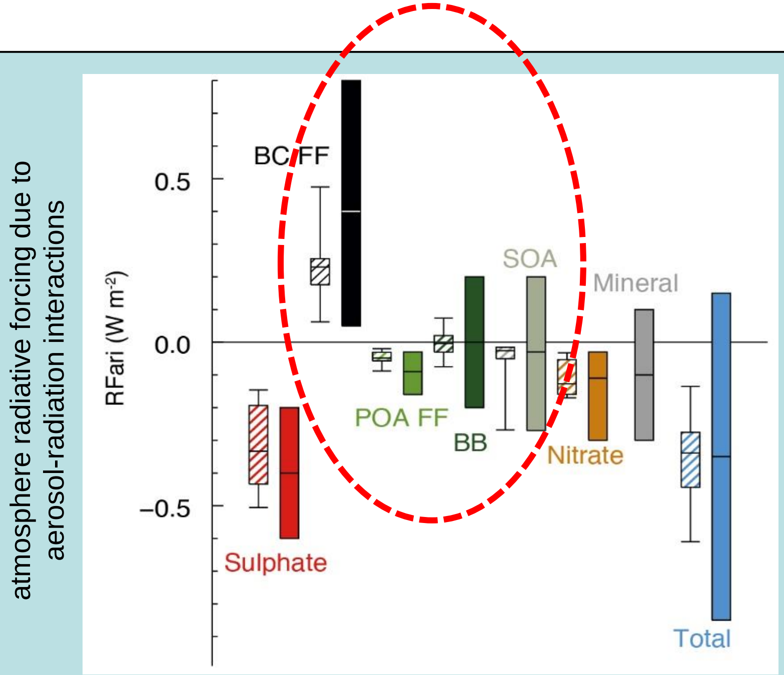
Stand-alone system for reliable determination of carbonaceous aerosol

Alejandro Keller, D. Heimann, P. Specht, P. Steigmeier, E. Weingartner

Importance of carbonaceous aerosol



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



IPCC, 2013: 5th Assessment Report (AR5)

Deposition of particles in human respiratory track

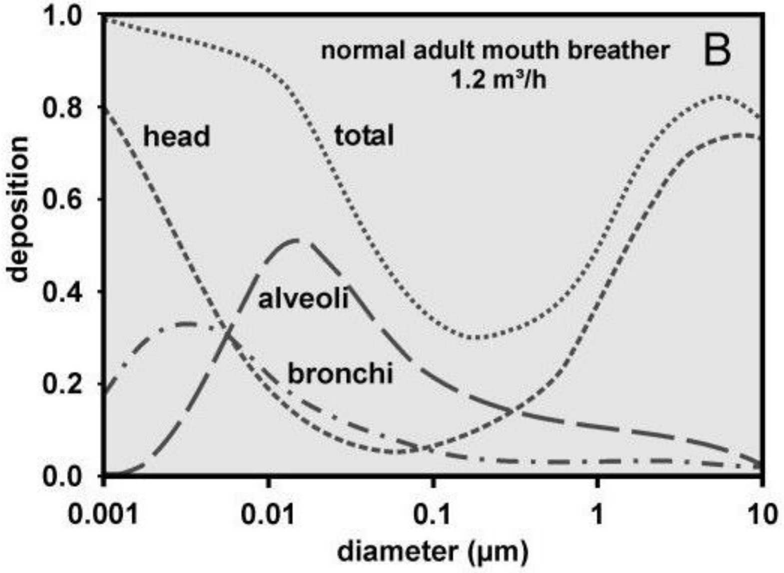


Figure: Geiser & Kreyling, 2010
https://doi.org/10.1186/1743-8977-7-2

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”

«We have to move away from methods that require filter collection»
Recently heard at a meeting with authorities from the Swiss meteorological organization

Temperature-controlled thermal evolution (EC/OC)

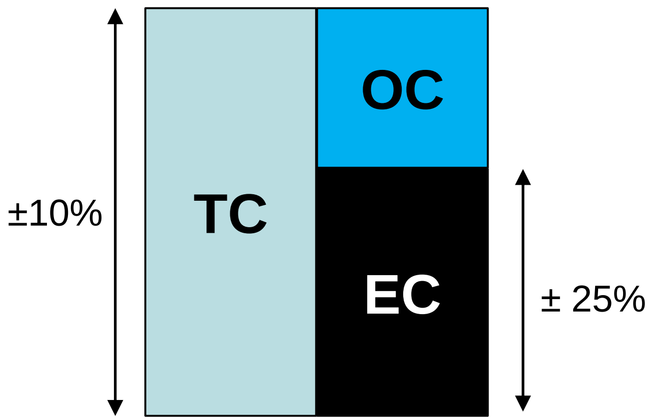
http://www.sunlab.com

	EPA/NIOSH[b]	NIOSH 5040	IMPROVE[c]	EUSAAR_1 short	EUSAAR_1 Long	He4-550	He4-750	He4-850	EUSAAR_2
STEP	*T*, duration °C, s	*T*, duration °C, s	*T*, duration °C, s	*T*, duration °C, s	*T*, duration °C, s	*T*, duration °C, s	*T*, duration °C, s	*T*, duration °C, s	*T*, duration °C, s
He1	310, 60	250, 60	120, 150–580	200, 120	200, 180	200, 180	200, 180	200, 180	200, 120
He2	475, 60	500, 60	250, 150–580	300, 150	300, 240	300, 240	300, 240	300, 240	300, 150
He3	615, 60	650, 60	450, 150–580	450, 180	450, 240	450, 240	450, 240	450, 240	450, 180
He4	900, 90	850, 90	550, 150–580	650, 180	650, 240	550, 240	750, 240	850, 240	650, 180
He/$O_2$1[a]	600, 45	650, 30	550, 150–580	550, 240	550, 300	550, 300	550, 300	550, 300	500, 120
He/$O_2$2	675, 45	750, 30	700, 150–580	850, 150	850, 180	850, 180	850, 180	850, 180	550, 120
He/$O_2$3	750, 45	850, 30	800, 150–580						700, 70
He/$O_2$4	825, 45	940, 120							850, 80
He/$O_2$5	920, 120								

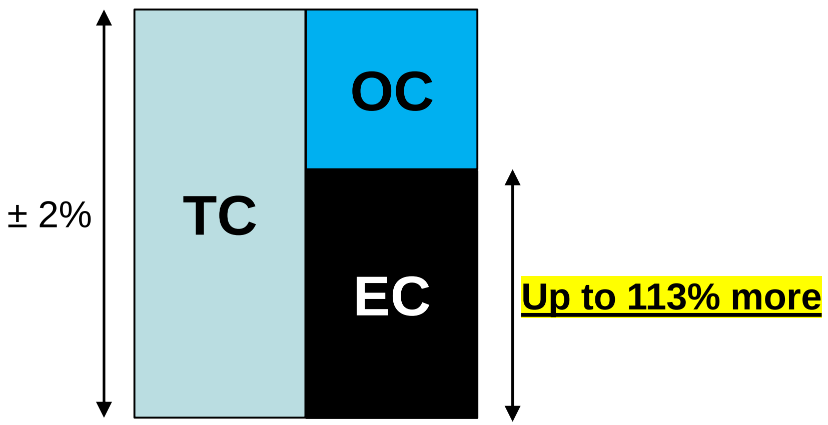
OC (He steps)
EC (He/O_2 steps)

Cavalli *et al.*, Atmos. Meas. Tech., 3, 79-89, 2010

Repeatability/reproducibility
Same protocol



Variation due to use of
Different protocol



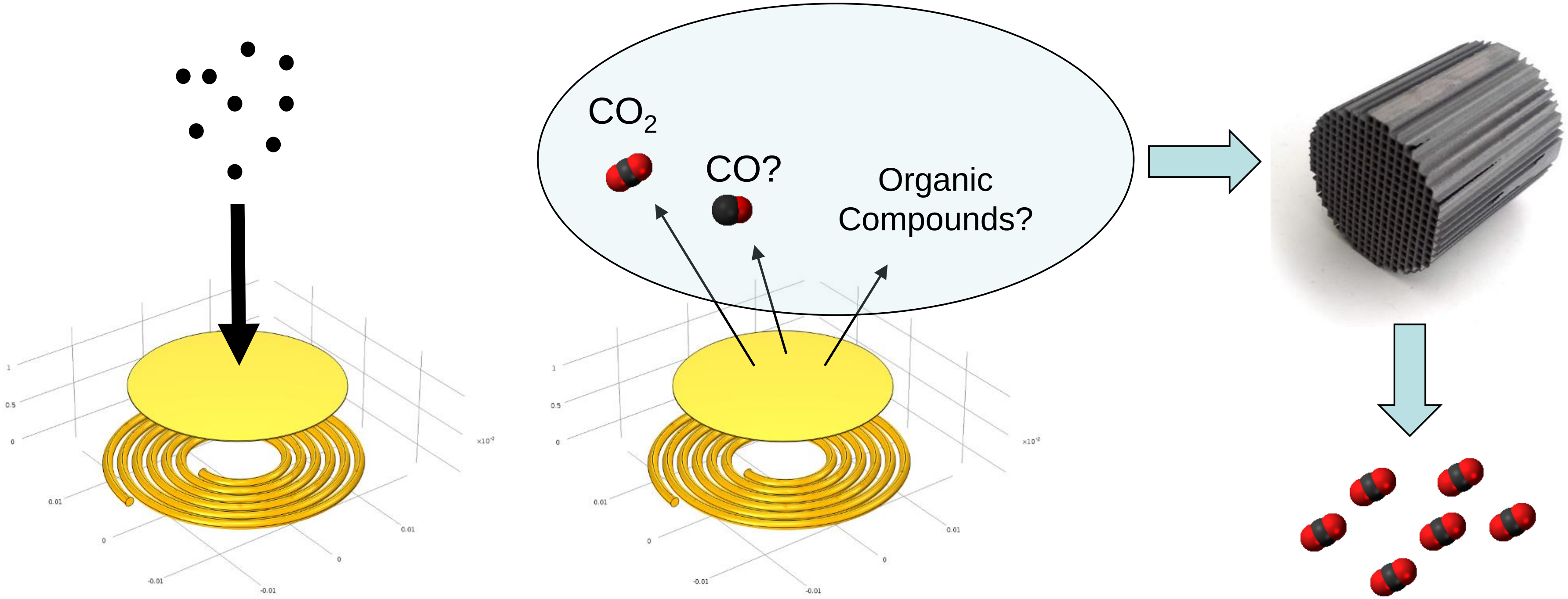
Biggest limitation: There is no reliable field measurement device for EC/OC analysis.

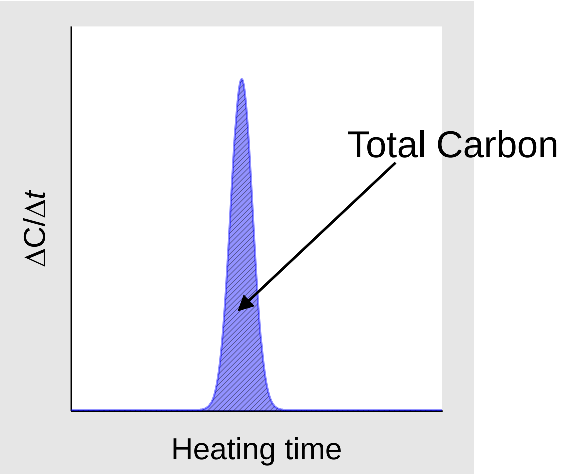
A simple and robust method is urgently needed.

See, e.g., Panteliadis *et al.*, Atmos. Meas. Tech., 8, 779-792, 2015

FAst Thermal CArbon Totalizer (FATCAT)

3. Catalytic converter



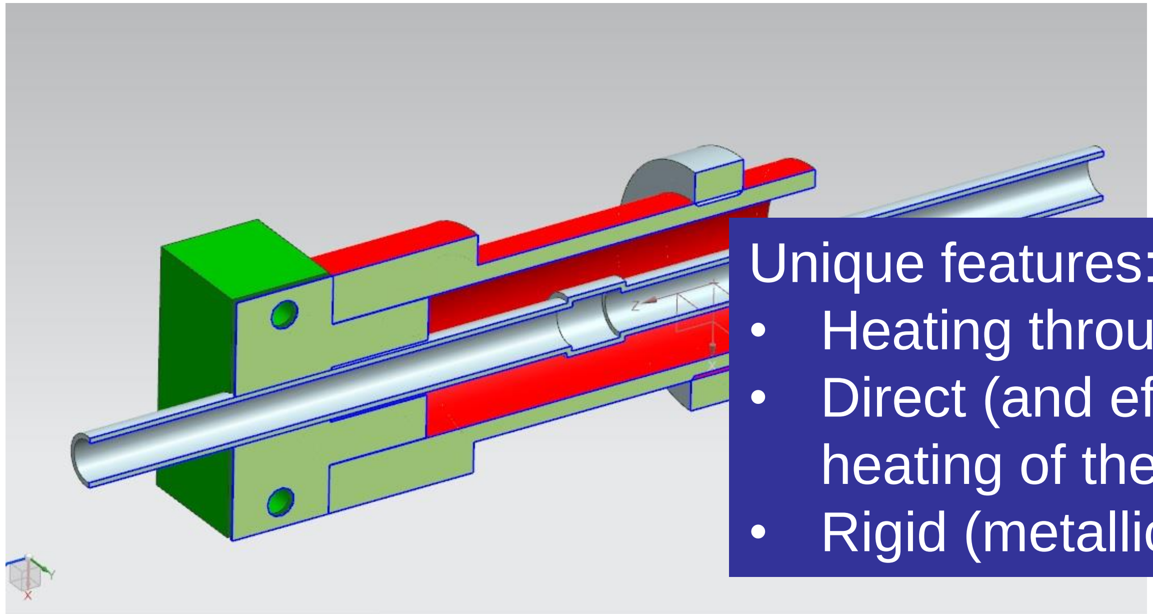


1. Capture particles on a filter

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

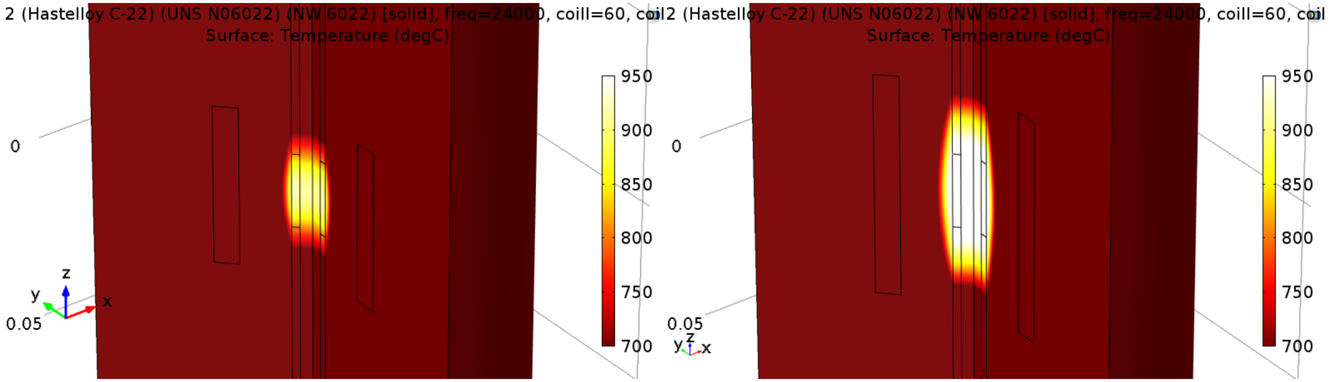
4. CO2 detection (NDIR)

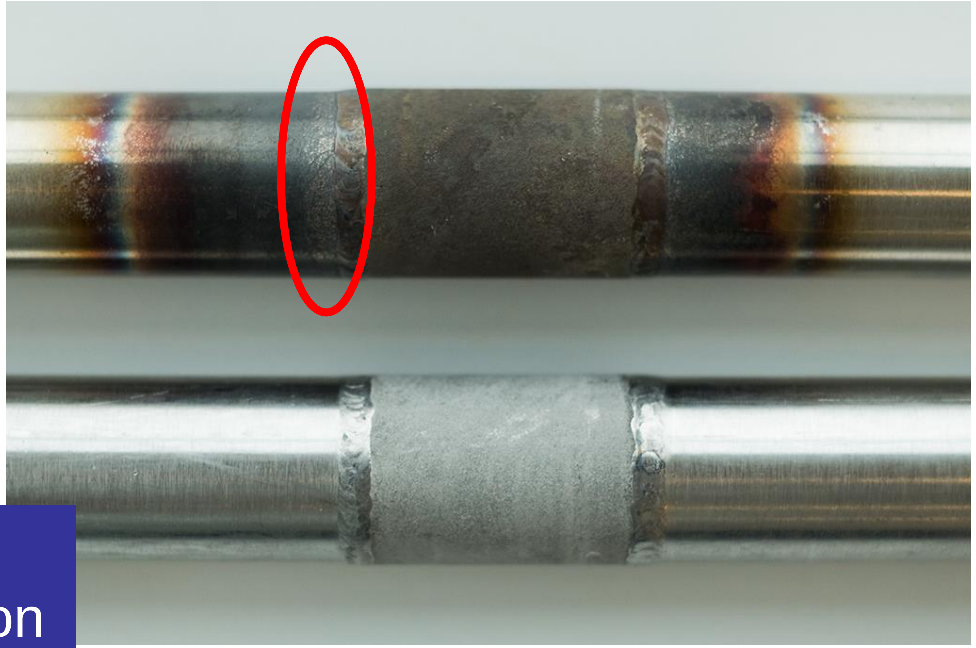
Filter optimization



Unique features:

- Heating through induction
- Direct (and efficient) heating of the filter
- Rigid (metallic) filter

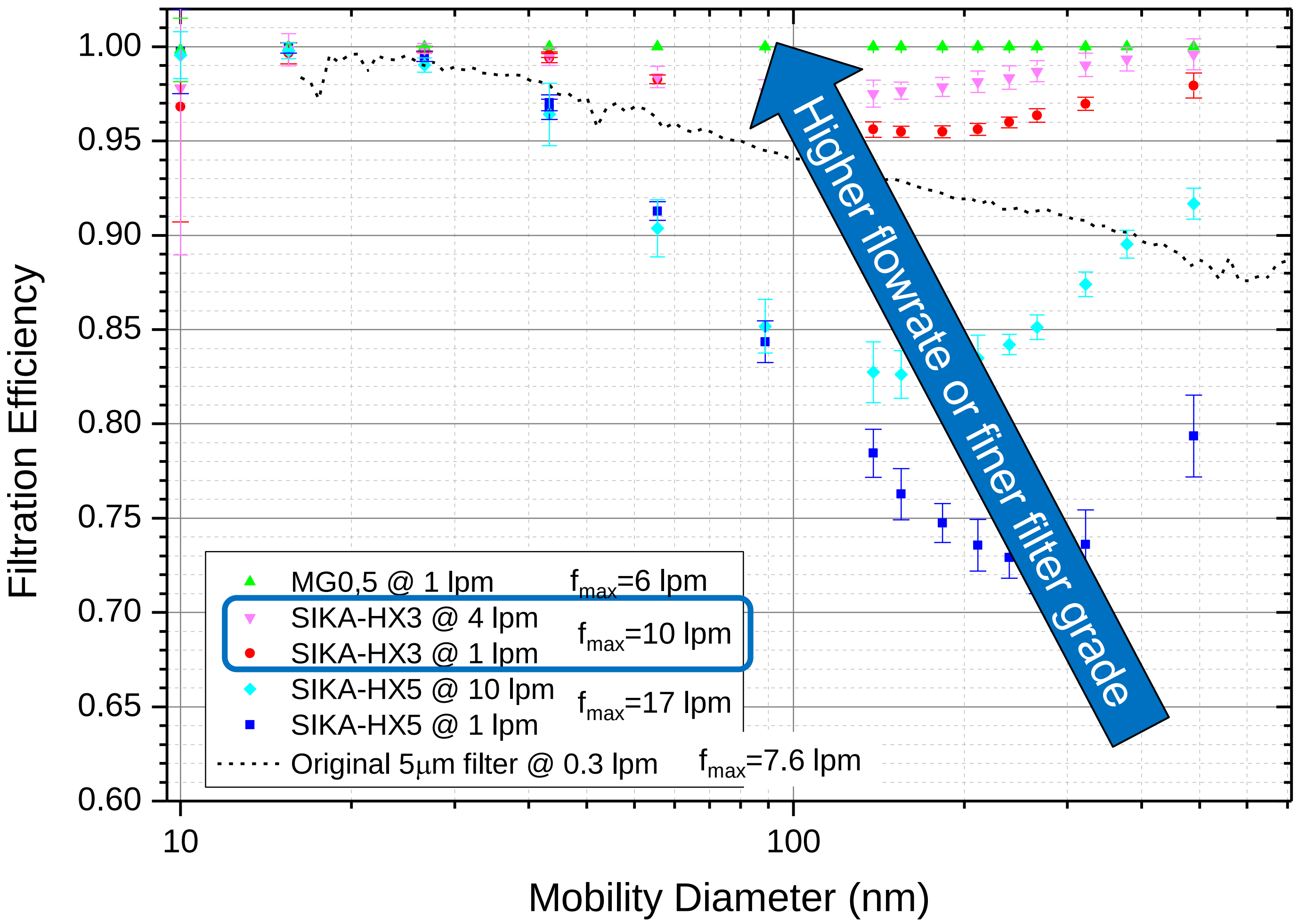


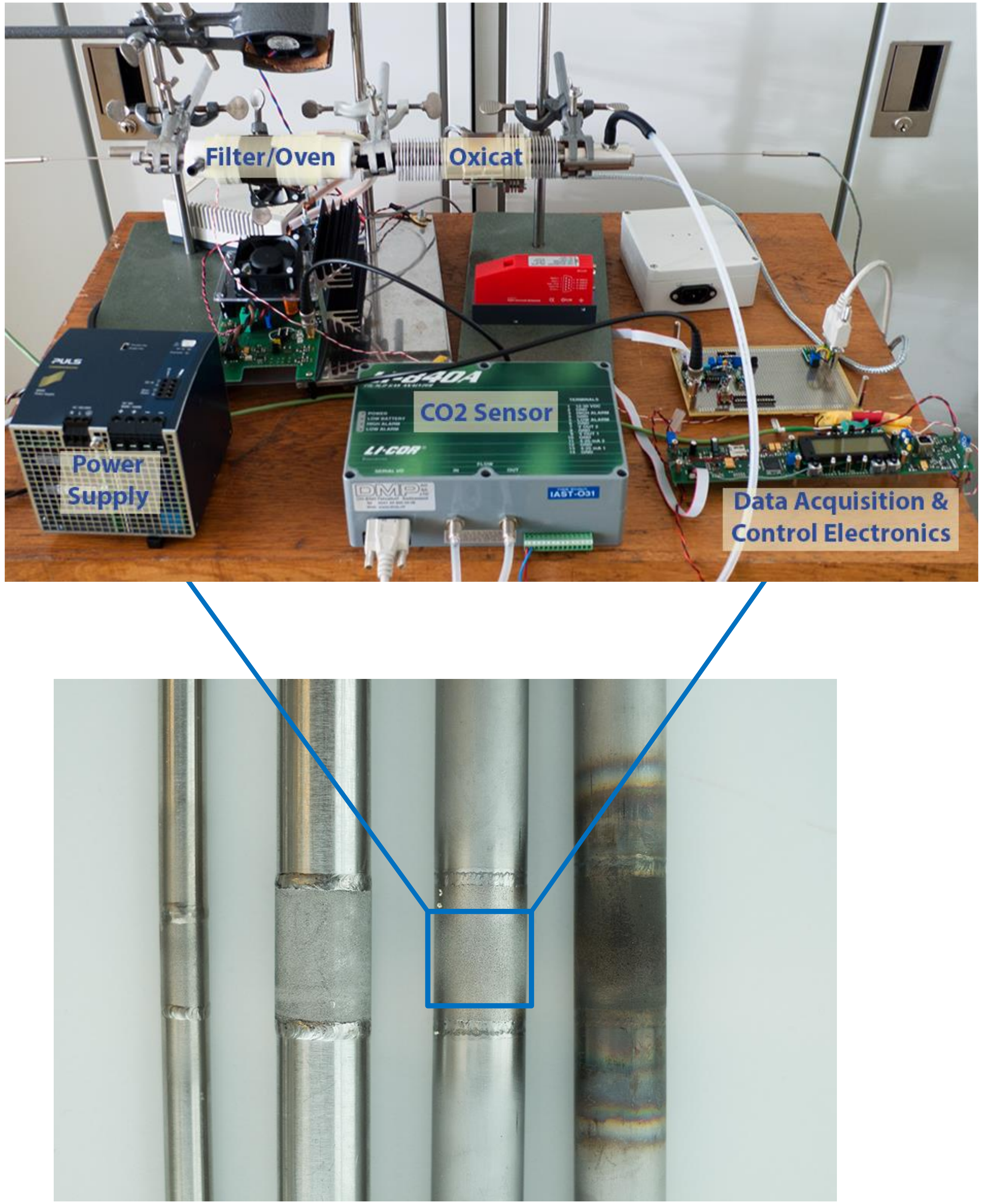


Used *vs.* new filter with 316SS tubing

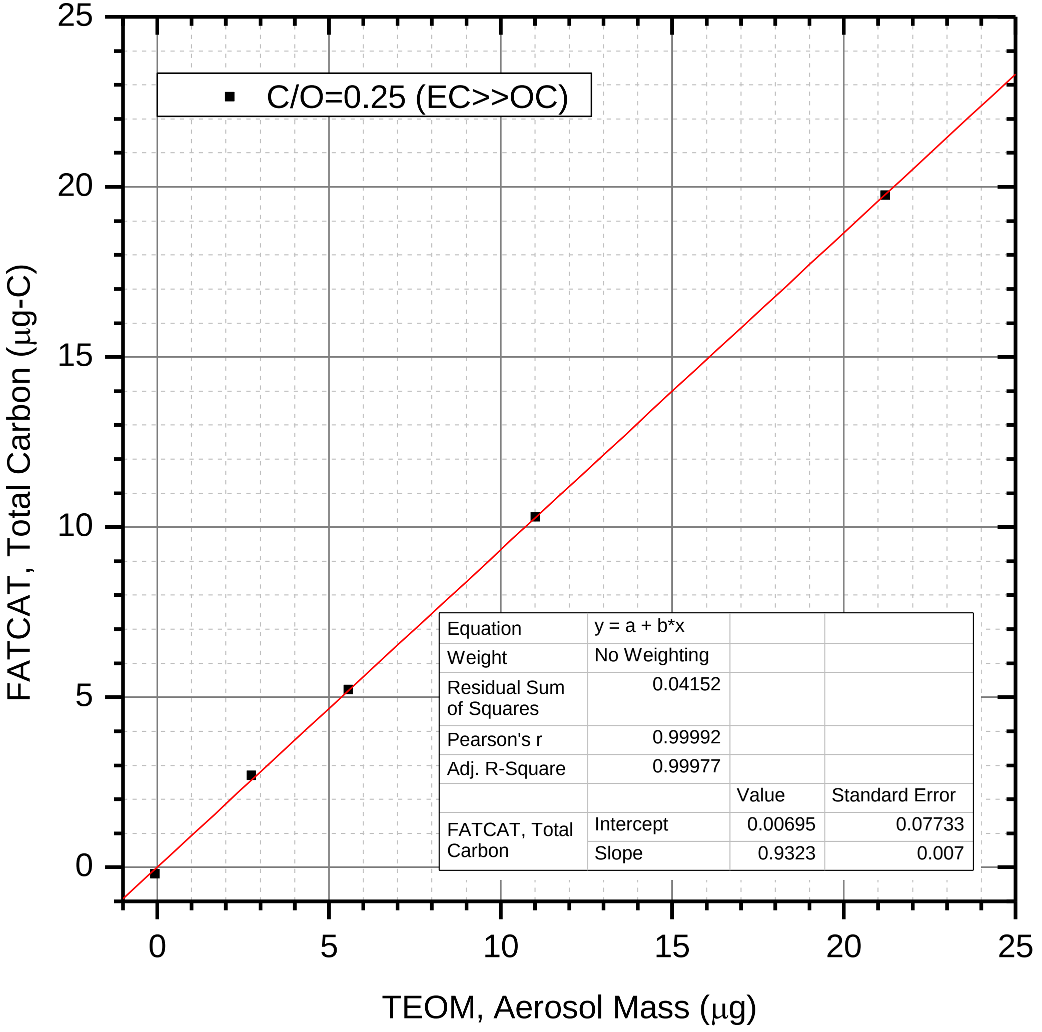
Iron splinters from damaged 316SS tubing (0.32 grams)

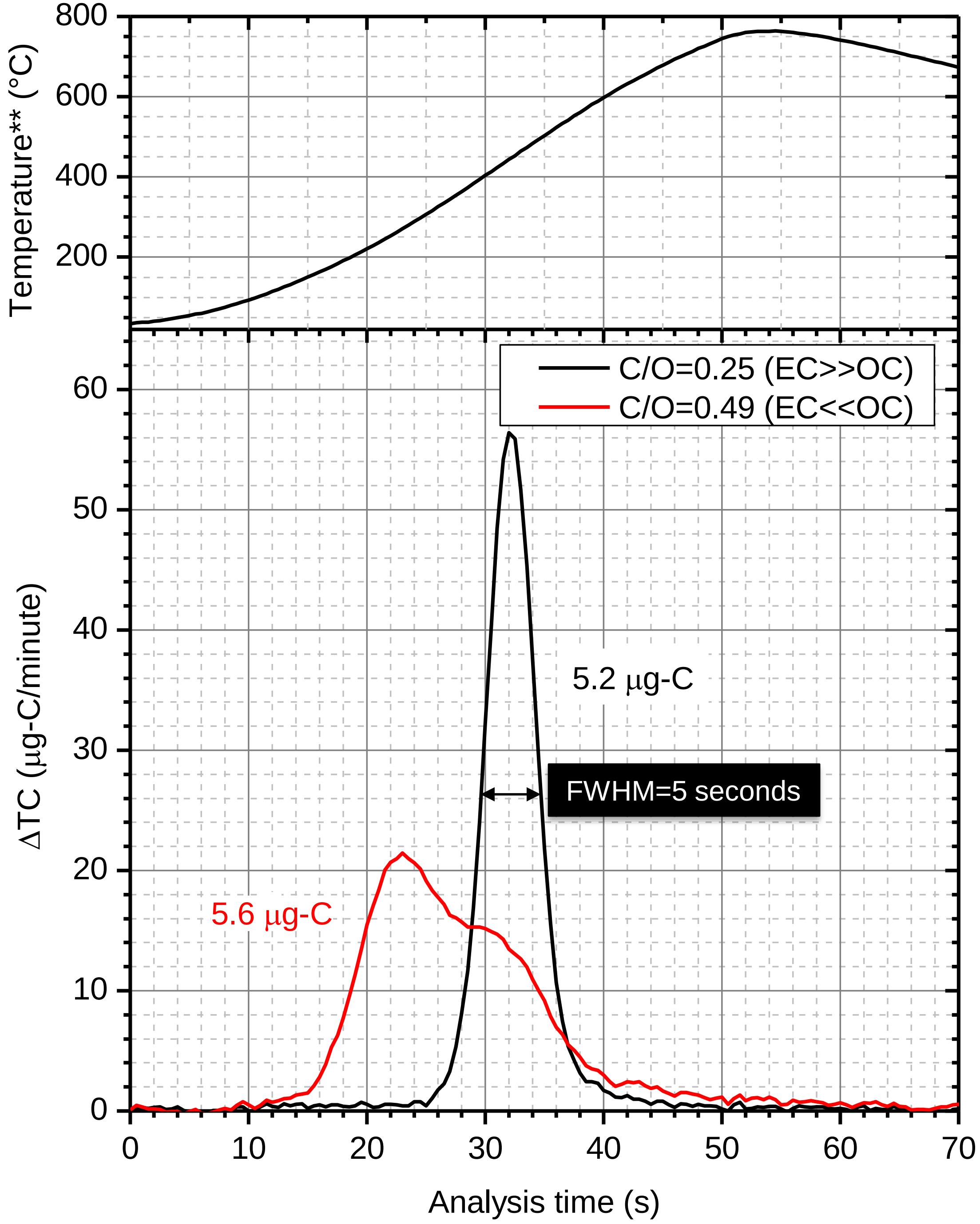
Filter optimization 2





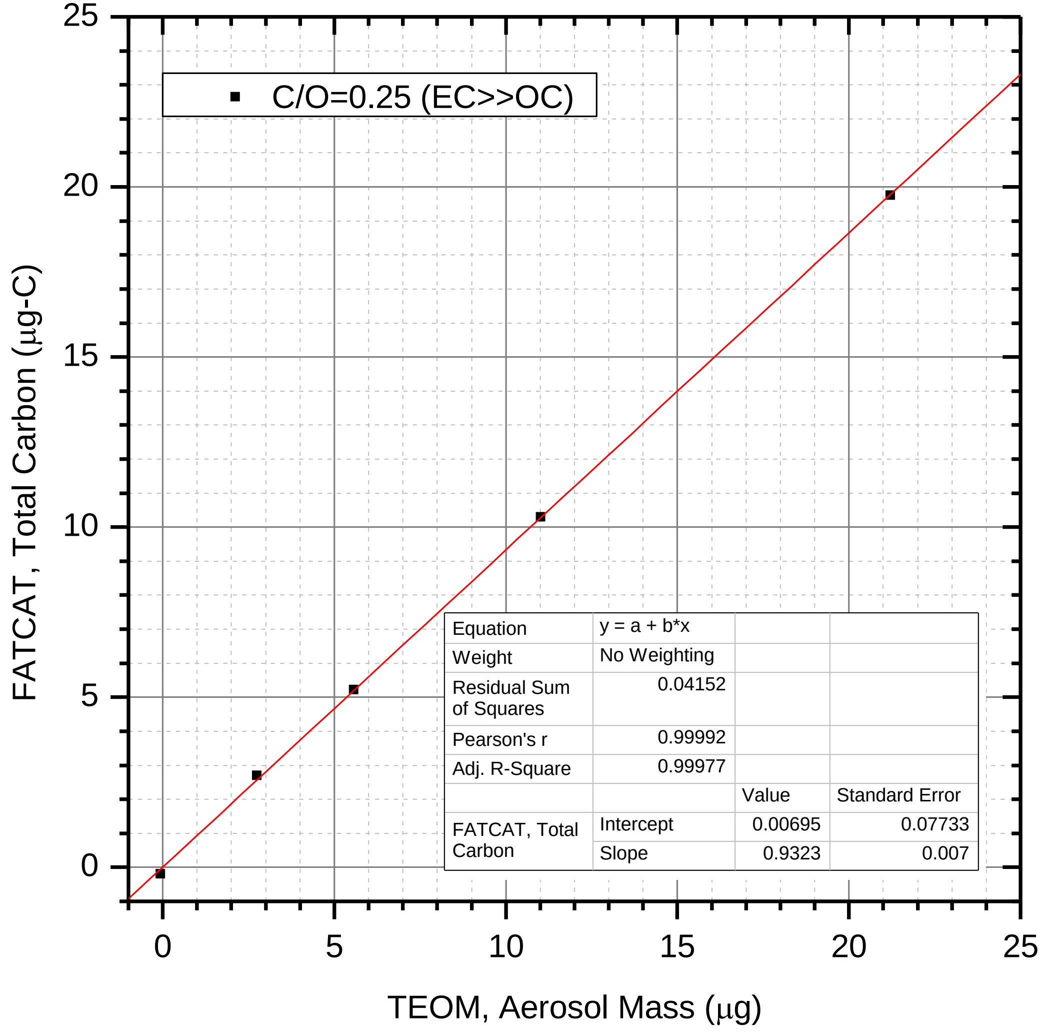
Characterization: Standard Soot*



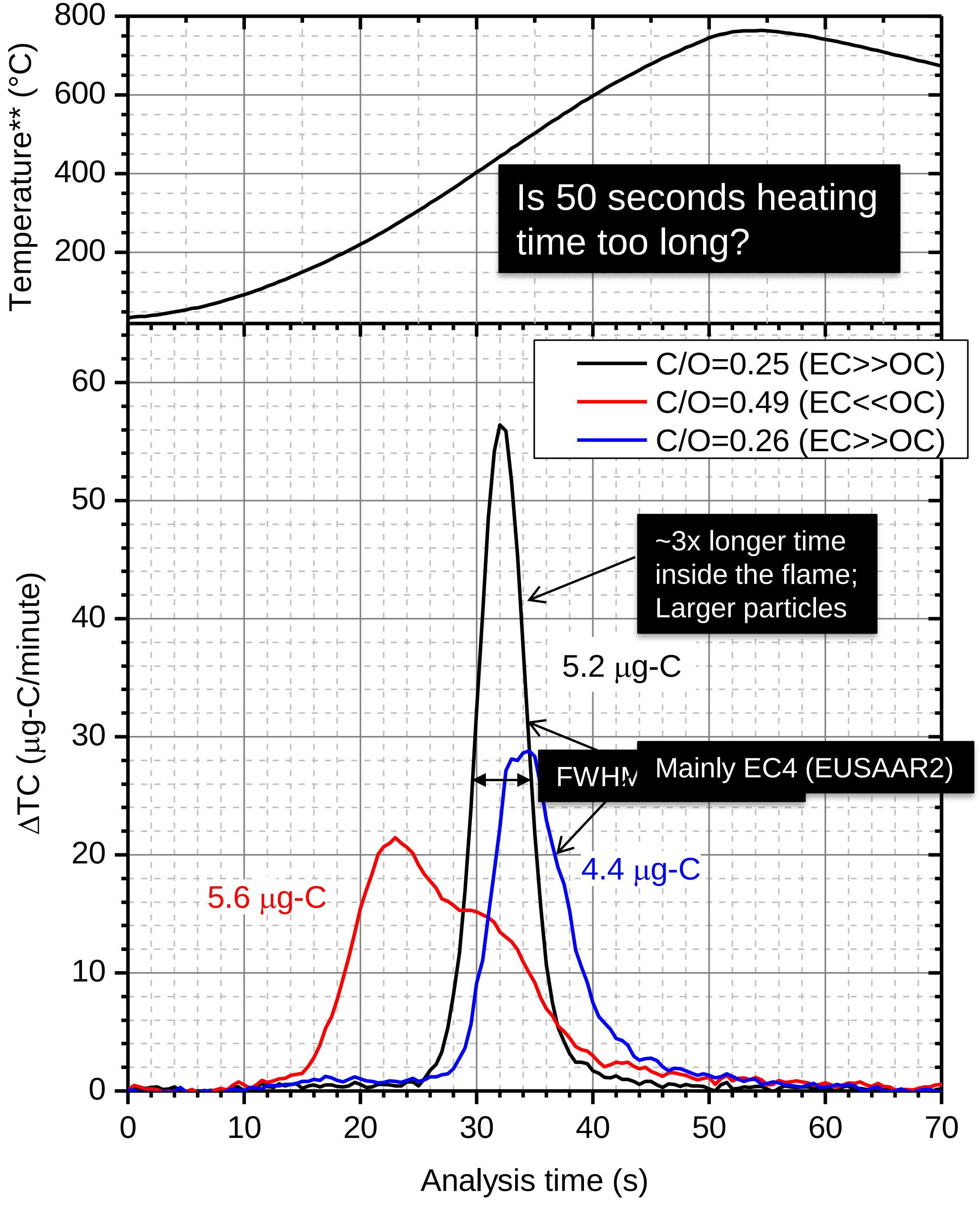


*Synthetic aerosol generated by means of a CAST (Jing, ag) diffusion flame generator.
**Temperature measured behind sampling filter. Actual filter temperature is higher.

Characterization: Standard Soot*



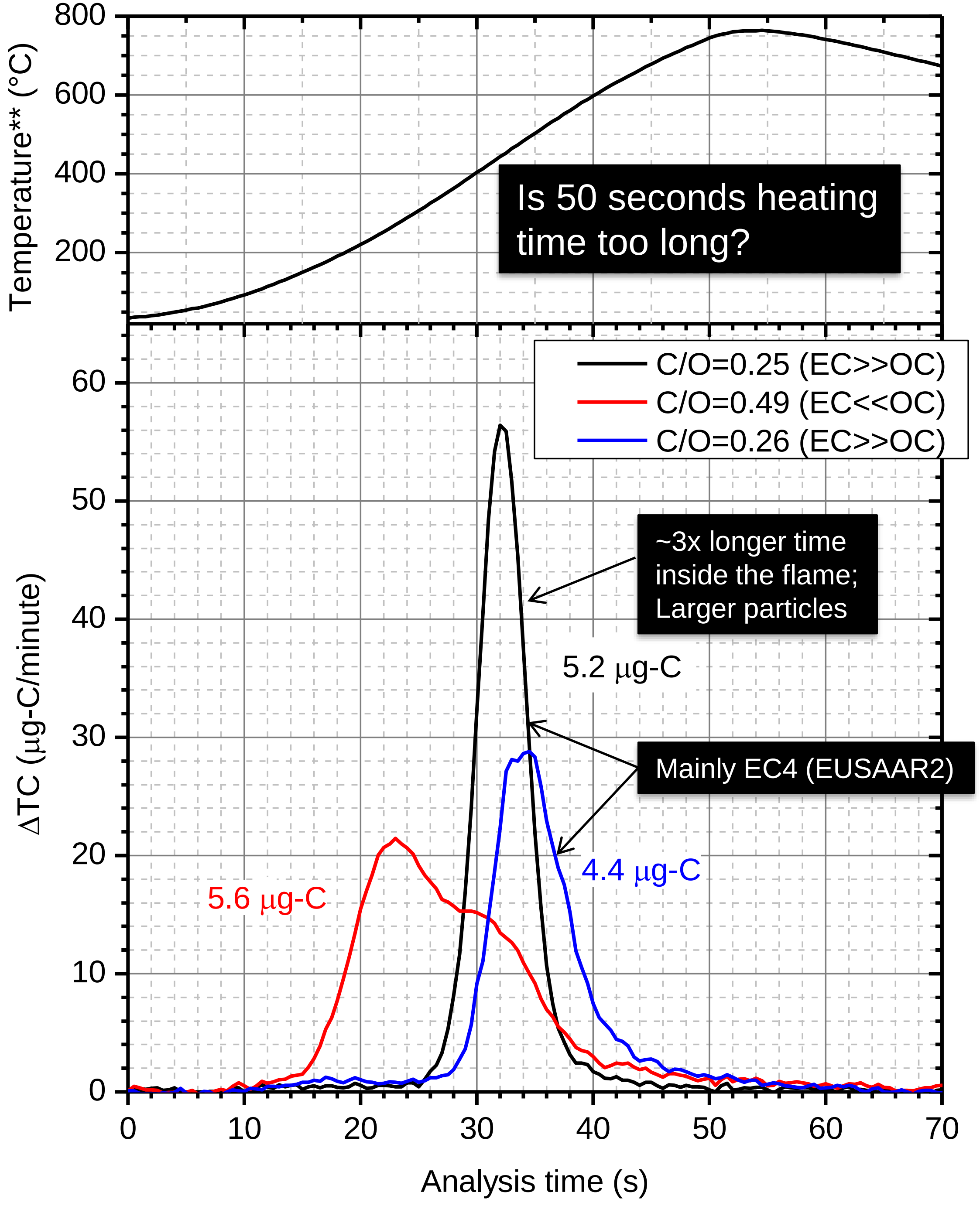
Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	0.04152		
Pearson's r	0.99992		
Adj. R-Square	0.99977		
		Value	Standard Error
FATCAT, Total Carbon	Intercept	0.00695	0.07733
	Slope	0.9323	0.007



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

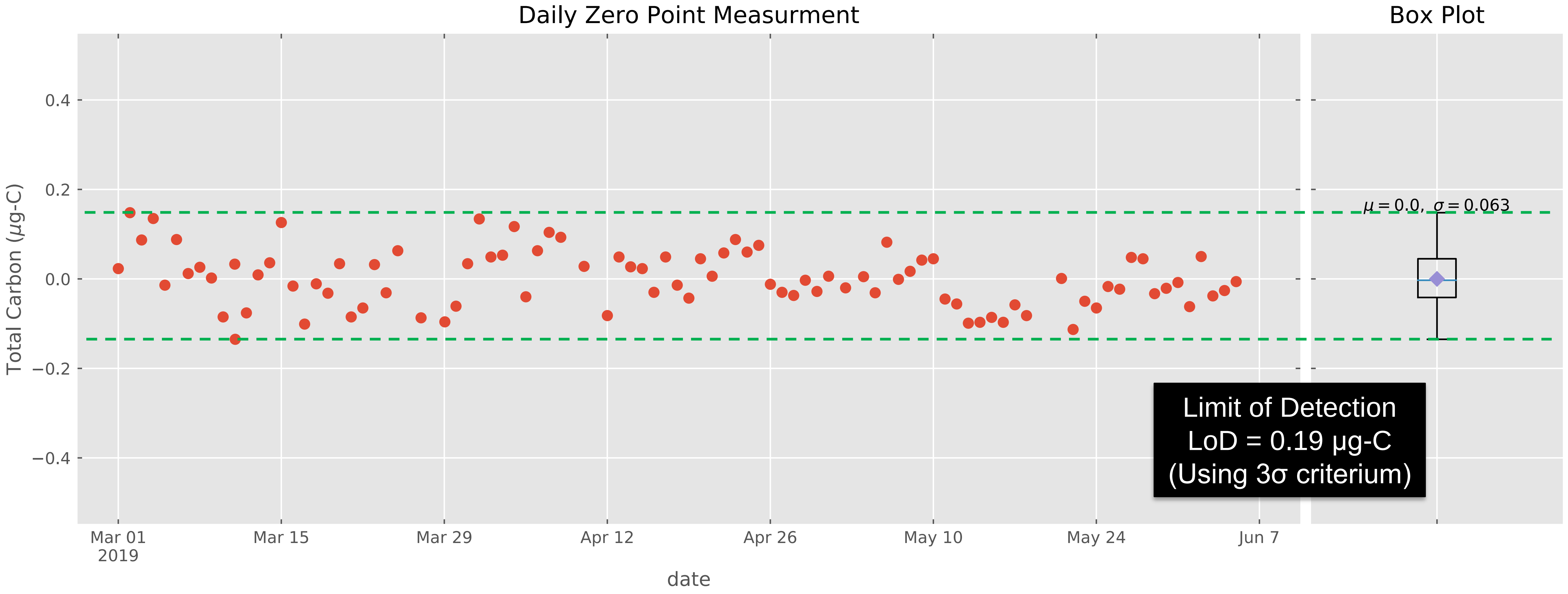
Characterization: Standard Soot*

- Thermal-optical protocols like, e.g., EUSAAR use between 800 and 940°C to combust the EC4 fraction.
- In our instrument 550°C, less than 40 seconds of heating, seem to be enough.
- Reducing heating/analysis time improves the limit of detection.
- Less heating also translates to faster instrument recovery.

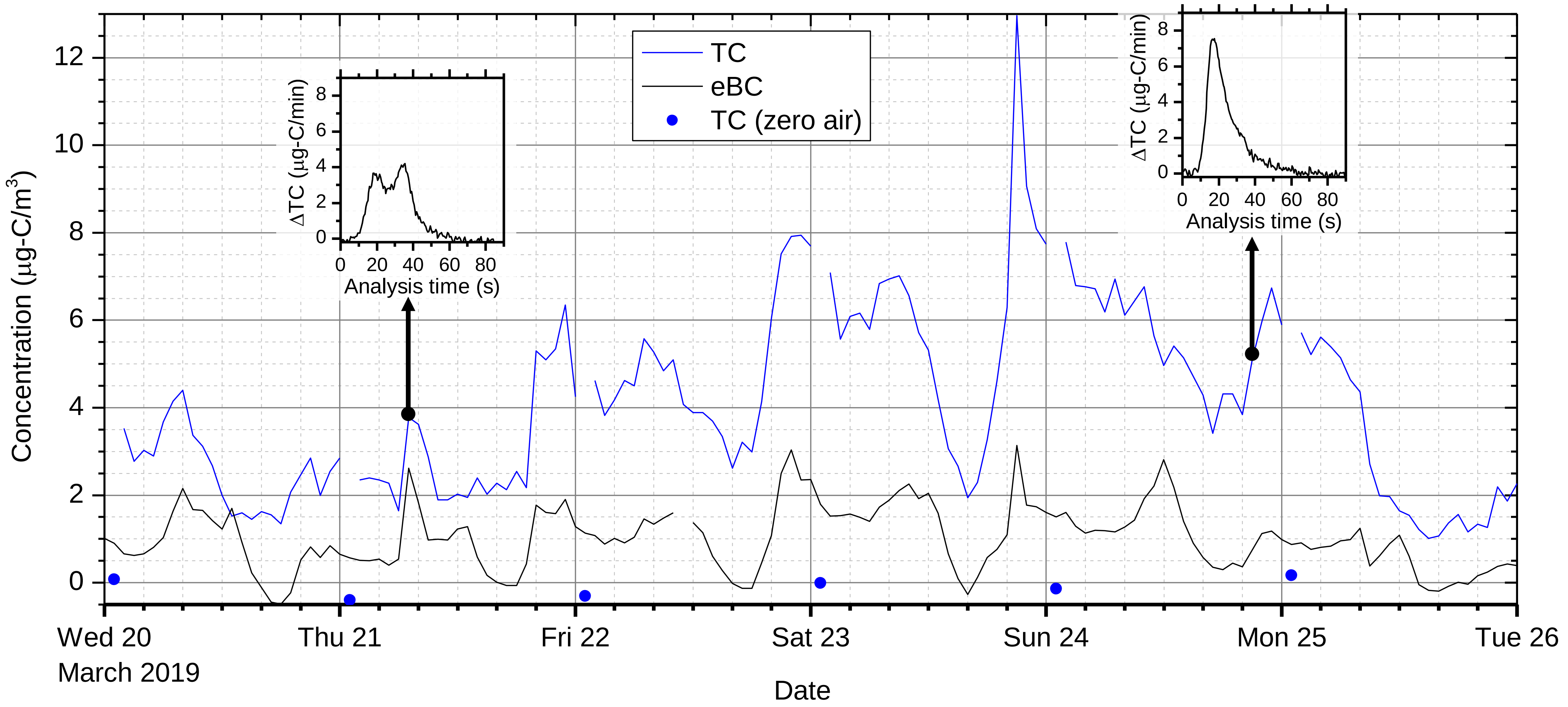


*Synthetic aerosol generated by means of a CAST (Jing, ag) diffusion flame generator.
**Temperature measured behind sampling filter. Actual filter temperature is higher.

Characterization: Zero measurements (preliminary results)

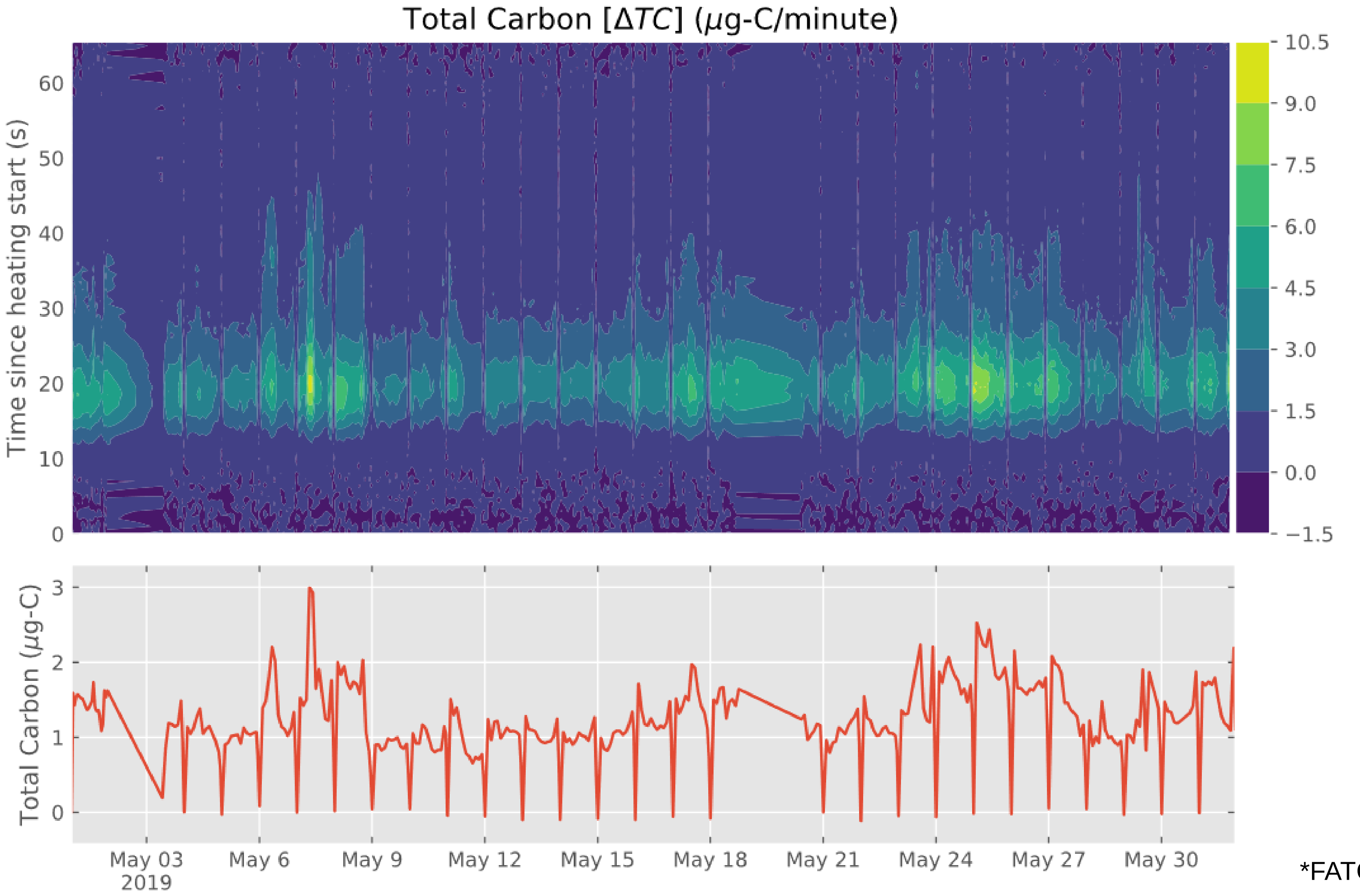


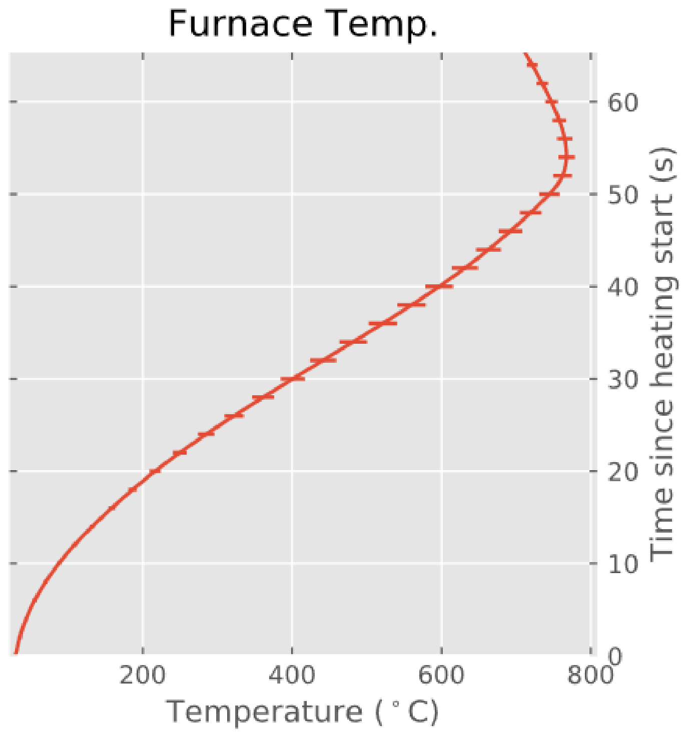
Characterization: Ambient air at Windisch (Aargau), Switzerland



FATCAT Sampling Volume: 0.4 m^3; Sampling Flow Rate: 8 lpm
eBC measured at λ=880nm (Aethalometer AE33, Magee Sci.)

Characterization: Ambient air at Windisch (Aargau), Switzerland



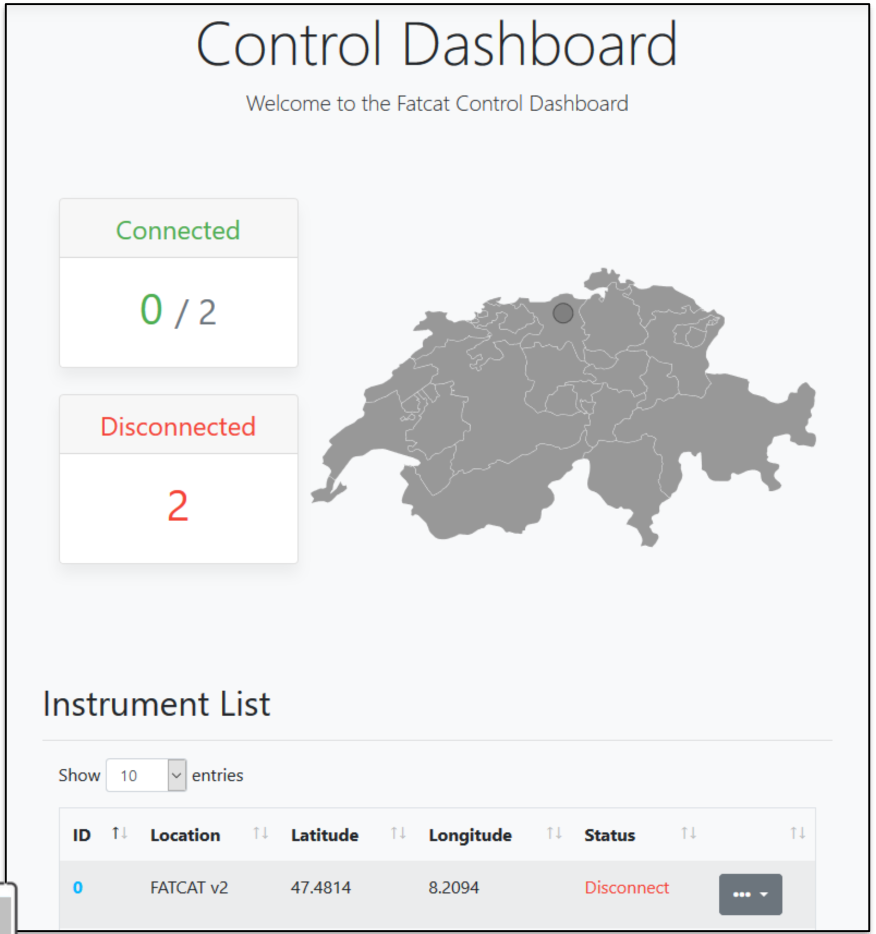


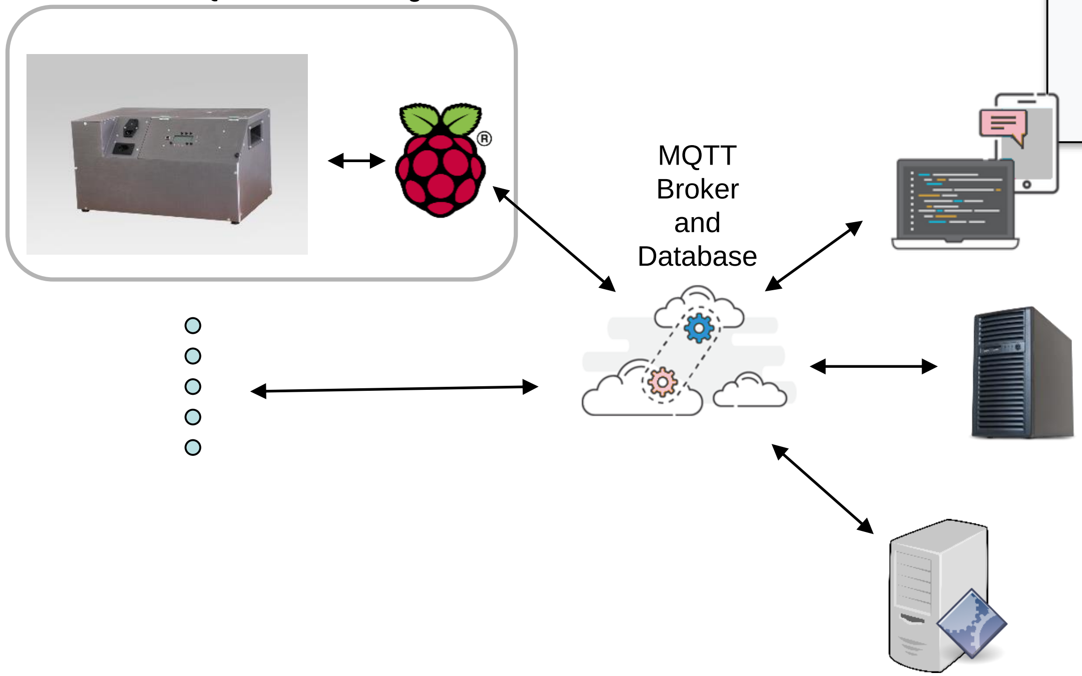
*FATCAT sampled volume was 0.44 m^3 for most datapoints

Cloud Interface

Operation modes:

- Manual: simple local GUI.
- Unattended, offline operation: scheduled operation, local data processing with automated upload of analysis files. Instrument accessible using remote terminal.
- Cloud operation: cloud interface, real time (or cued) upload of sensor data (with local backup), data analysis in cloud, local scheduling (reprogrammable through cloud broker).

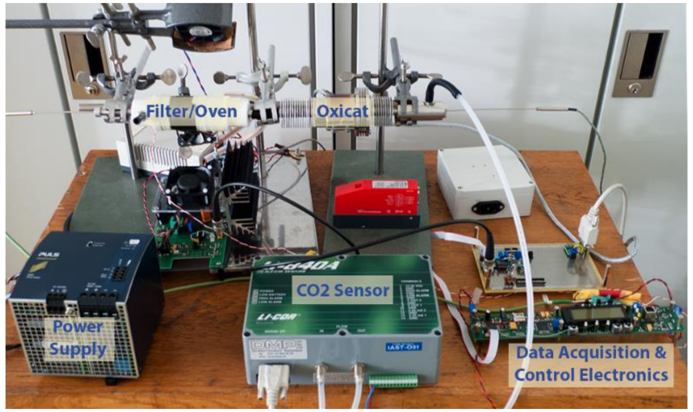


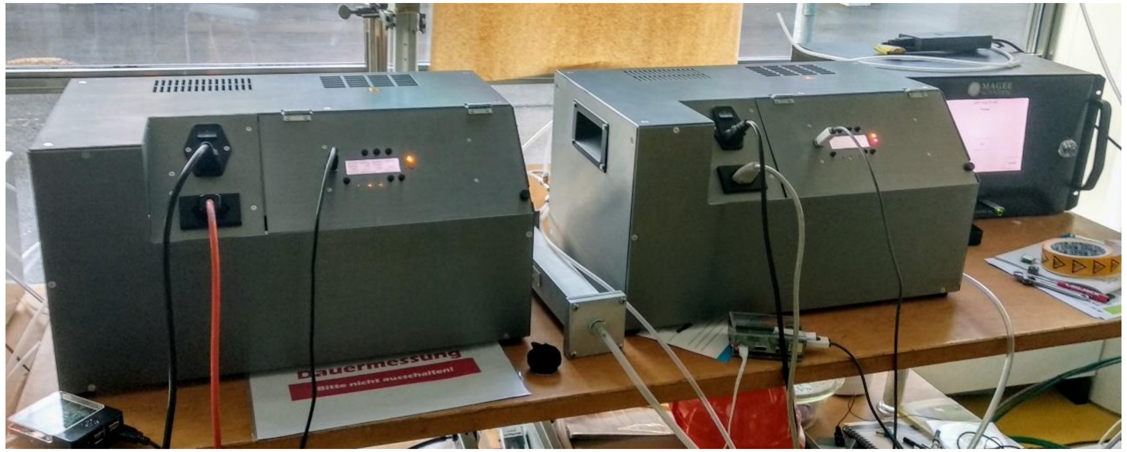


The new TCA-8 from Aerosol d.o.o. is similar, but uses a soft quartz filter

Operational field instrument

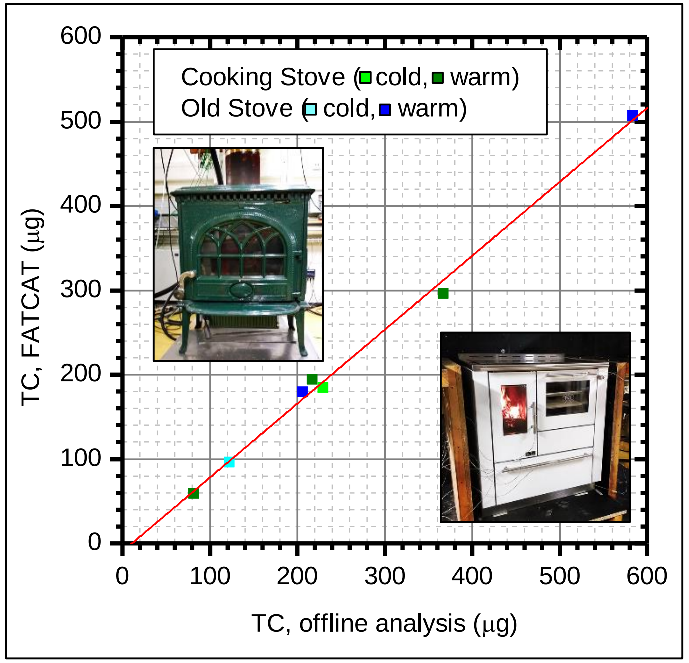
- Stable, robust, and simple system
- Simpler and less expensive measurement cycle
- Short analysis time (translates to better limit of detection)
- High dynamic range [0.2 to > 500 µg-C] (top limit still not stablished)
- **Unique:** Rigid and stable filter (no filter displacements or leaks)
- **Unique:** 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





Possible optimizations

- Further filter optimization to, e.g., increase sample flow rate (current maximum: 10lpm) [low priority]
- Improved filter temperature monitoring (shorter heating, faster recovery) [medium priority]
- Preconditioning unit for analysis air (currently using Synthetic Air) [high priority, ongoing]
- Dual sampling head to eliminate recovery time after analysis [low priority]
- Cloud software optimization for, e.g., email alarms, behavior during long network-out periods, etc [medium priority, under evaluation]
- App development [low priority]



Measurements using the original laboratory setup

Planned activities 2019

- Characterization of the instrument using laboratory sources and comparison against thermal-optial methods [ongoing]
- Measurement of emissions from biomass burning appliances at a test bench
- Long time measurements to establish performance for stand-alone operation [ongoing] (next to other aerosol instruments at Windisch and selected NABEL measurement stations)
- Publication of technical paper to describe the performance of the new instrument
- Deployment at the MeteoSwiss/NABEL measurement station in Payern, Switzerland, next to other aerosol instruments (with PSI/EMPA)

We are looking for partners for characterization or for other areas of application of our measurement system.

Please challenge FATCAT with interesting measurement activities!

Acknowledgements

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Funding has been provided by the Swiss Federal Office for the Environment (FOEN) & MeteoSwiss

Dr. A. Mayer
Hug Engineering (oxidation catalyst)
J. Curiel (Cloud Software)