Development of a semi-continuous measurement system for the carbonaceous fraction in ambient aerosol

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FAst Thermal CArbon Totalizator (FATCAT)

About this project

Within the framework of the MeteoSwiss Global Atmosphere Watch (GAW) program GAW-Plus 2018-2021, we are developing a carbonaceous aerosol measurement system for long-term monitoring of total carbon (TC). The instrument will be a redesign of the FAst Thermal CArbon Totalizator (FATCAT), a successfully tested technology for emission monitoring developed by our research group. The standardization and the development of a simplified continuous TC measurement method aim to fill a major gap in the GAW aerosol monitoring program, i.e., to provide an affordable method of carbonaceous aerosol measurement at monitoring sites and to assure comparability of data measured by different research groups.

Planed activities include several unsupervised long-term measurement campaigns at monitoring stations, within the Swiss National Air Pollution Monitoring Network (NABEL) network as well as on the GAW Jungfraujoch site, which are influenced by different types of carbonaceous aerosol throughout the year. The resulting dataset and post-analysis data products represent an upgrade to the available measurement inventory and serve as quality control for other measurement techniques. Prominently, measurements of equivalent black carbon via MAAP or Aethalometer and organic mass using AMS or ToF-ACSM require calibration and are susceptible to systematic errors. Our unattended semi-online TC measurement can be used in parallel to these devices to warranty mass closure.

Motivation

Due to its importance for the direct and indirect aerosol effects on climate (figure 1), carbonaceous matter is among the core parameters recommended for permanent monitoring at GAW sites by the Scientific Advisory Group (SAG) on their 2003 and 2016 guidelines (WMO/GAW, 2003; WMO/GAW, 2016). In spite of the SAG recommendation, there is no permanent monitoring of carbonaceous aerosol beyond equivalent black carbon in any GAW global station. Fractions like the organic aerosol mass – a major component of the atmospheric aerosol (figure 2) – are only available for few short-duration supervised measurement campaigns. New measurement techniques and more robust devices are required to improve this situation. Comprehensive long-term measurements of aerosol composition and physical properties are of paramount importance for assessing aerosol effects on climate and health and for devising effective mitigation strategies.

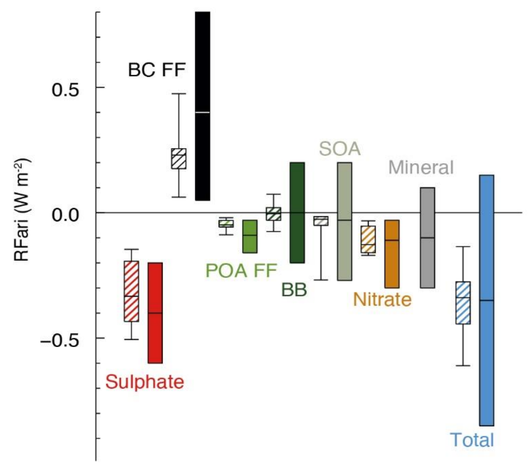


Figure 1. Atmosphere radiative forcing due to aerosol-radiation interactions (Rfari). The largest uncertainty corresponds to the carbonaceous aerosol fraction. Dashed bars show the data from the 4th IPCC Assessment Report (2007). Newer data is presented as solid bars. Source: IPCC 5th Assessment Report (AR5), 2013.

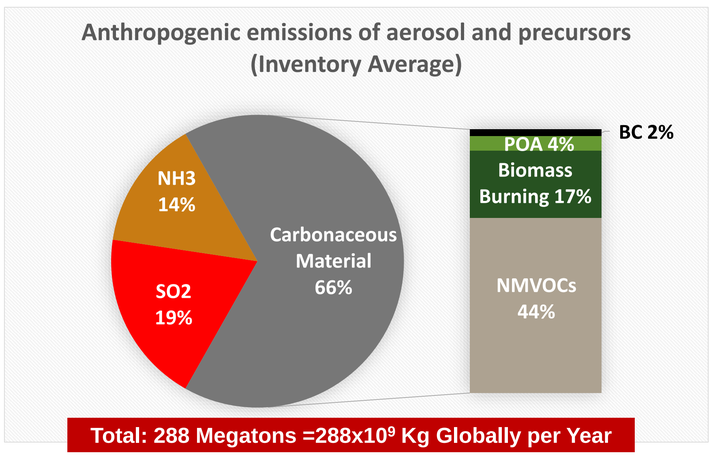


Figure 2. Carbonaceous aerosol (and carbonaceous aerosol-precursors) comprises the largest fraction of anthropogenic emissions. Adapted from IPCC 5th Assessment Report (AR5), 2013.

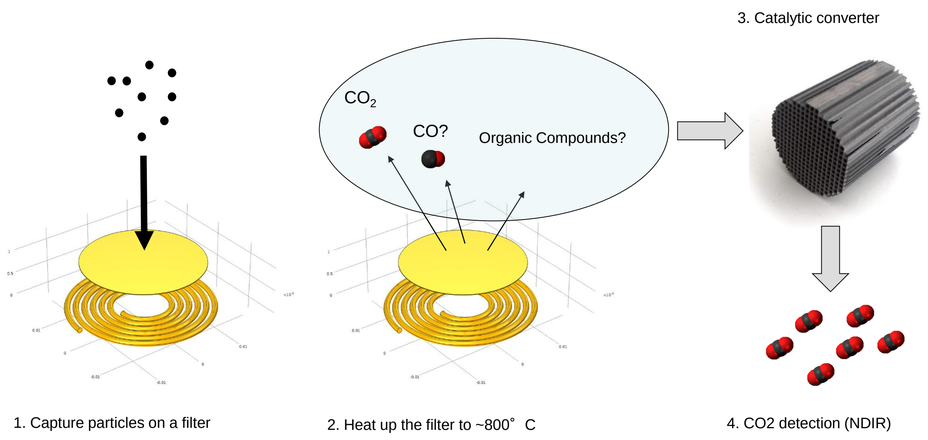
Advantages compared to commercial solutions

- **Stable, robust, and simple system:** All components are independent and have a long lifetime. In contrast, a widely used commercial solution requires a replacement of the whole heating system together with the oxidation agent typically once a year.
- **Simpler and less expensive measurement cycle:** we do not require several analysis gases or a separation of carbonaceous fractions.
- **Shorter analysis time:** Heating time of less than one minute. One order of magnitude faster than thermal-optical protocols. This translates into a **better limit of detection** as it creates an enrichment of the carbon signal.
- **Rigid and stable filter:** No filter displacement errors (a major problem of commercial analyzer) and the possibility of using higher sampling flow rates, which reduce collection time and/or increases the limit of detection.

Work packages

- Optimization of the current TC Analyzer for the unattended deployment in the field (-> better stability and lower detecting limits)
- Deployment in the Swiss National Air Pollution Monitoring Network (NABEL) stations next to state-of-the-art instruments at urban and rural sites during different seasons.
- Deployment at the Jungfraujoch GAW global station next to aerosol instrumentation (including a ToF-ACSM measuring organic aerosol) during different seasons.
- Intermittent measurement with our oxidation flow reactor, the Micro Smog Chamber, to access the SOA formation potential.
- Measurements are complemented with the new PTI device (i.e. photothermal interferometer; for more details see poster by Weingartner *et al.*) being developed at our laboratory, from which precise equivalent black carbon concentrations can be inferred.

How does FATCAT work



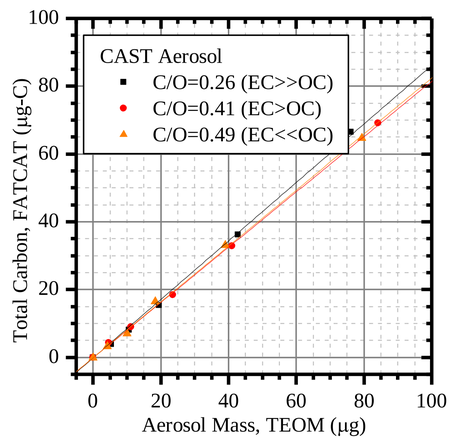


Figure 3. Total carbon *vs.* total aerosol mass for diverse carbonaceous-aerosol samples. Lines are linear fits (coefficient of determination $R^2_{adj} \geq 0.998$).

Acknowledgments

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Further reading

Bruns *et al.*, "Inter-comparison of laboratory smog chamber and flow reactor systems on organic aerosol yield and composition," Atmos. Meas. Tech., **8**, 2315-2332, 2015.

Keller & Burtscher, "A continuous photo-oxidation flow reactor for a defined measurement of the SOA formation potential of wood burning emissions," Aerosol Sci. **49** pp. 9-20, 2012.