BC Measurement Overview, and Considerations for a Community Approach to Measurement

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Outline

Commercial measurement options for BC light absorption

Potential biases for all measurement options

Removal of semi-volatile material

Why the community needs BC light absorption (mass)

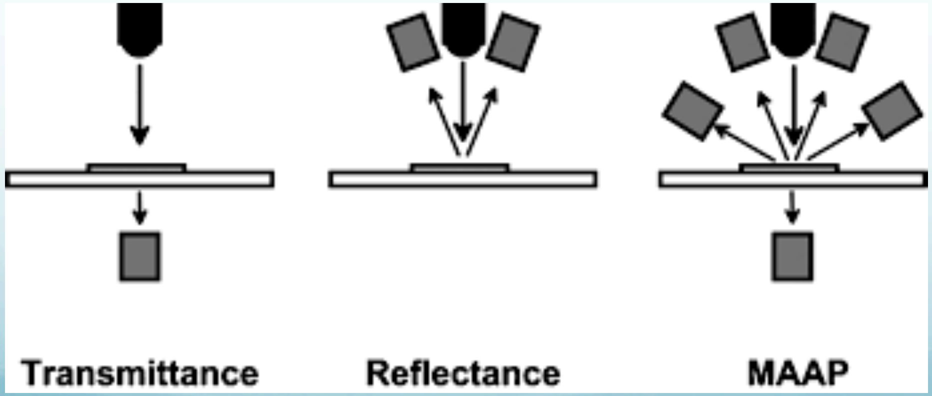
Commercial measurement options for BC light absorption

- Photoacoustic Absorption Spectrometer
  - Independently validated → used to validate lower accuracy measurements.
  - Accuracy: 5%
  - Cost: $$$
  - Biases: NO_2, Coatings

- Filter-Based Absorption – MAAP
  - Accuracy: ~10%
  - Cost: $$
  - Biases: Scattering, coatings

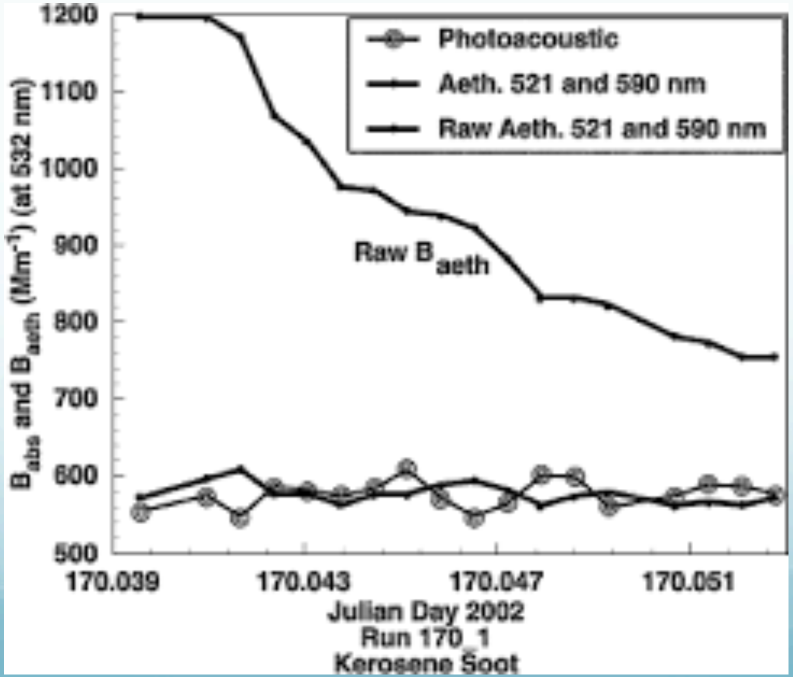
- Filter-Based Absorption – Aethelomter, PSAP, COSMOS.
  - Accuracy: 30-40%
  - Cost: $
  - Biases: Scattering, coatings, particle size, filter type, particle loading.

- Filter-Based Extinction – FSN, bosch number etc.
  - Accuracy: Not applicable
  - Cost: $
  - Biases: Correction to absorption, scattering, coatings, particle size, filter type, particle loading.

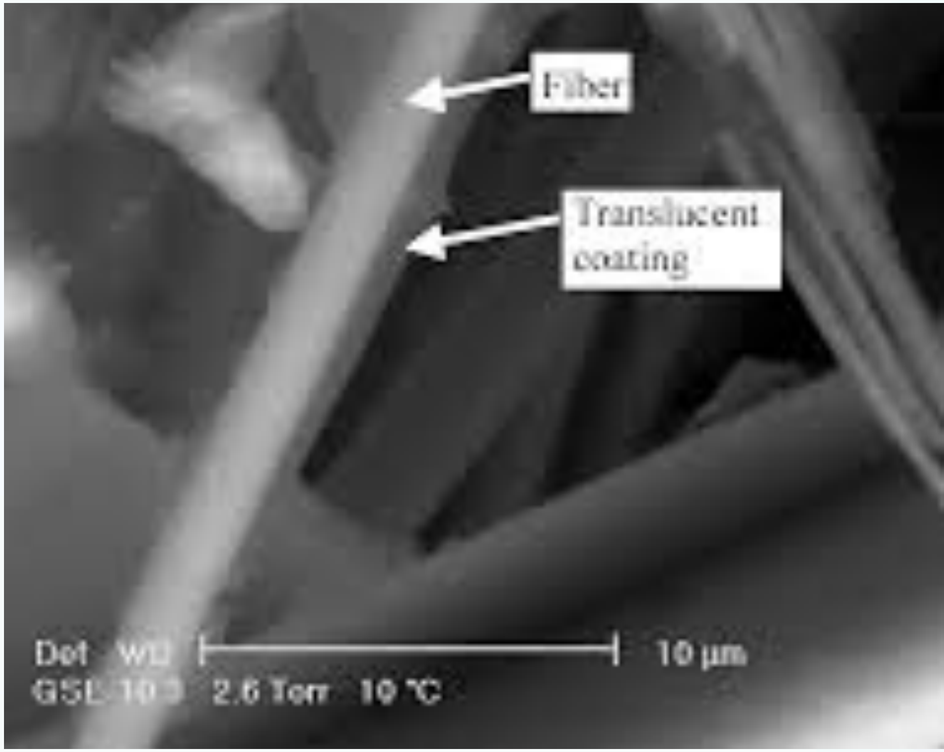


Light Absorption Biases

- Scattering Material + Filter Fibers
  - SO_4, Organics
  - Particles and filter material scatters light → measured as excess absorption
  - Can bias filter-based by >100%
  - Particle loading progressively increases bias.



- Liquid Material
  - Organics
  - Liquid coats filter fibers
    - Changes optics of fibers.



the solid black line is a least-square fit to the data, the dashed line is the
1:1 agreement between PSAP and PAS, the grey points are individual c
from which bin averages are obtained. Size of the binned data points
abundance of data in each OA mass bin and uncertainty bars are 1
reproduction of Figure 4b showing the individual data points color
fraction of OOA to total OA. Black solid line is the linear fit to all da
black lines are linear fits to the 25% of data having the lowest ar
fractions of OOA. Expected 1:1 line is also included.

- Other Biases
  - Dilution: Affects gas-particle partitioning of semi-volatile scattering particles
  - RH/Pressure: affects properties of filters
  - Flow Rate:
  - Filter Size:
  - Particle Size

Brown Carbon (BrC)

- Brown carbon is likely to contribute <10% of light absorption.
- Brown carbon contributes to biases in measurement.
- For the purposes of accurate measurements, BrC should be removed through sample heating.

Filter-Based Absorption Correction Methods

- PSAP, MAAP, Aethelometer, COMOS have undergone multiple laboratory and field inter-comparison and validation trials.
  - Particle type.
  - Particle size.
  - Scattering contributions → Single Scatter Albedo
  - Filter loading

1.Collaud Coen M, *et al.* (2010) Minimizing light absorption measurement artifacts of the Aethalometer: evaluation of five correction algorithms. *Atmos. Meas. Tech.* 3(2):457-474.
2.Virkkula A (2010) Correction of the Calibration of the 3-wavelength Particle Soot Absorption Photometer (3 λ PSAP). *Aerosol Science and Technology* 44(8):706 - 712.
3.Petzold A, *et al.* (2005) Evaluation of multiangle absorption photometry for measuring aerosol light absorption. *Aer. Sci. Tech.* 39(1):40-51.
4.Irwin M, Kondo Y, & Moteki N (2015) An empirical correction factor for filter-based photo-absorption black carbon measurements. *Journal of Aerosol Science* 80(0):86-97.
5.Arnott WP, Hamasha K, Moosmuller H, Sheridan PJ, & Ogren JA (2005) Towards Aerosol Light-Absorption Measurements with a 7-Wavelength Aethelometer: Evaluation with a Photoacoustic Instrument and 3-Wavelength Nephelometer. *Aerosol Science and Technology* 39(1):17-29.
6.Hansen ADA, Rosen H, & Novakov T (1984) The aethelometer - An instrument for the real-time measurement of optical absorption by aerosol particles. *Science of the Total Environment* 36:191–196.
7.Weingartner E, *et al.* (2003) Absorption of Light by Soot Particles: Determination of the Absoprtion Coefficient by means of Aethelometers. *Aerosol Science* 34:1445-1463.
8.Sheridan PJ, *et al.* (2005) The Reno Aerosol Optics Study: An Evaluation of Aerosol Absorption Measurement Methods. *Aerosol Sci. Tech.* 39(1):1.
9.Bond TC, Anderson TL, & Campbell D (1999) Calibration and Intercomparison of Filter-Based Measurements of Visible Light Absorption by Aerosols. *Aerosol Sci. Tech.* 30(6):582.
10.Ogren JA (2010) Comment on - Calibration and Intercomparison of Filter-Based Measurements of Visible Light Absorption by Aerosols. *Aerosol Science and Technology* 44(8):589 - 591.
11.Petzold A & Schönlinner M (2004) Multi-angle absorption photometry - a new method for the measurement of aerosol light absorption and atmospheric black carbon. *Journal of Aerosol Science* 35(4):421-441.
12.Kondo Y, *et al.* (2009) Stabilization of the Mass Absorption Cross Section of Black Carbon for Filter-Based Absorption Photometry by the Use of a Heated Inlet. *Aerosol Sci. Tech.* 43(8):DOI: 10.1080/02786820902889879.
13.Kondo Y, *et al.* (2011) Consistency and Traceability of Black Carbon Measurements Made by Laser-Induced Incandescence, Thermal-Optical Transmittance, and Filter-Based Photo-Absorption Techniques. *Aerosol Sci. Tech.* 45(2):295-312.
14.Miyazaki Y, *et al.* (2008) Performance of a newly designed continuous soot monitoring system (COSMOS). *Journal of Environmental Monitoring* 10(10):1195-1201.
15.Nakayama T, *et al.* (2010) Size-Dependent Correction Factors for Absorption Measurements using Filter-based Photometers: PSAP and COSMOS. *J. Aerosol. Sci.* 41(4):333-343.

Sample Pre-Treatment

- Well controlled sample pre-treatment is as important as measurement choice.
- **Control of**:
  - Dilution, RH, Pressure, Temperature
- **Removal of**:
  - Semi-volatiles
  - NO_2 (if PAS)

will minimise biases in ALL measurement methods.

- Sample heating to 150 – 300 °C removes most semi-volatile components.
  - But different temperatures remove different amounts
  - Needs to be standardised.
- Convergence of BC absorption after sample pre-treatment with heating.

Why do we need an accurate measure of absorption?

- BC absorption and mass are the units used for regulation, control, climate/health impacts.
- BC absorption can be converted to BC mass by using a single conversion factor.
  - Accuracy of this factor is debatable but so long as it is known, interchange is possible.
- Filter-based absorption (MAAP, PSAP, Aethelometer, COSMOS) have variable accuracies even with thousands of hours of laboratory corrections
- FSN: Is an un-calibrated precise unitless number, but
  - Cannot be compared to other measurements
  - Cannot be used for regulatory, air quality, climate work.
  - Cannot know what the true contribution of BC is.

  - It does have the potential to join the ranks of other filter-based methods.

Take Home Message

- Precise and accurate BC absorption/mass measurement are available if some simple standardisations are made by the community.
- Research, industry and regulators have contributions to make, but cannot exchange data unless they work within these standards.