Filter-based optical instruments for BC determination

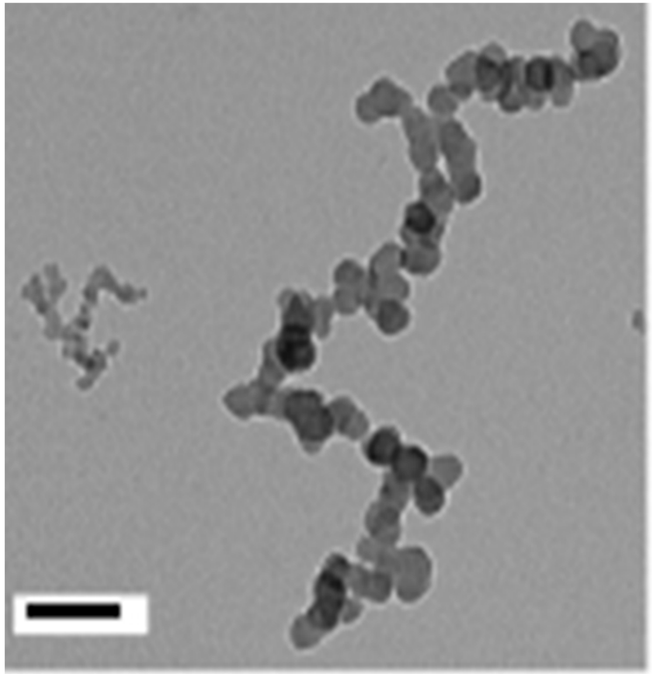
Dr. Patricia Krecl

ATMOSPHER
Laboratory for Urban Air Pollution and Climate

UTFPR

Soot particles

- Carbonaceous particles emitted by incomplete combustion
- Fraction of $PM_{2.5}$, aggregate of small carbon spheres (10-50 nm)
- Refractory, with vaporization T ~4000 K
- Insoluble in water and common organic solvents
- Strong absorption of VIS radiation
- High sp^2-bonded carbon content



Source: Steven Rogak (UBC-Canada)

Bond et al., 2013; Petzold et al,2013; Lack et al., 2014

Measurement techniques

PROPERTIES

Based on light absorption — **eBC**
- **Filter-based optical methods**
- Photo-acoustic techniques
- Photo-thermal interferometry

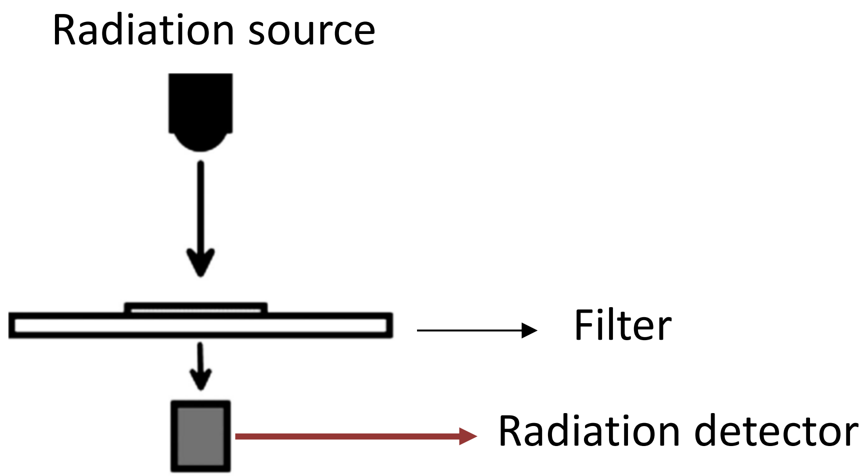
Based on combustion properties; sp^2 bonded carbon; carbon content — **EC**
- Thermal and thermal optical analysis
- Raman spectroscopy
- Aerosol mass spectroscopy

Based on refractory — **rBC**
- Incandescence methods (LII, SP2)

Petzold et al,2013; Lack et al., 2014

Filter-based optical methods

Measurement of the light transmittance through a particle-loaded filter at short intervals (even < 1 min).



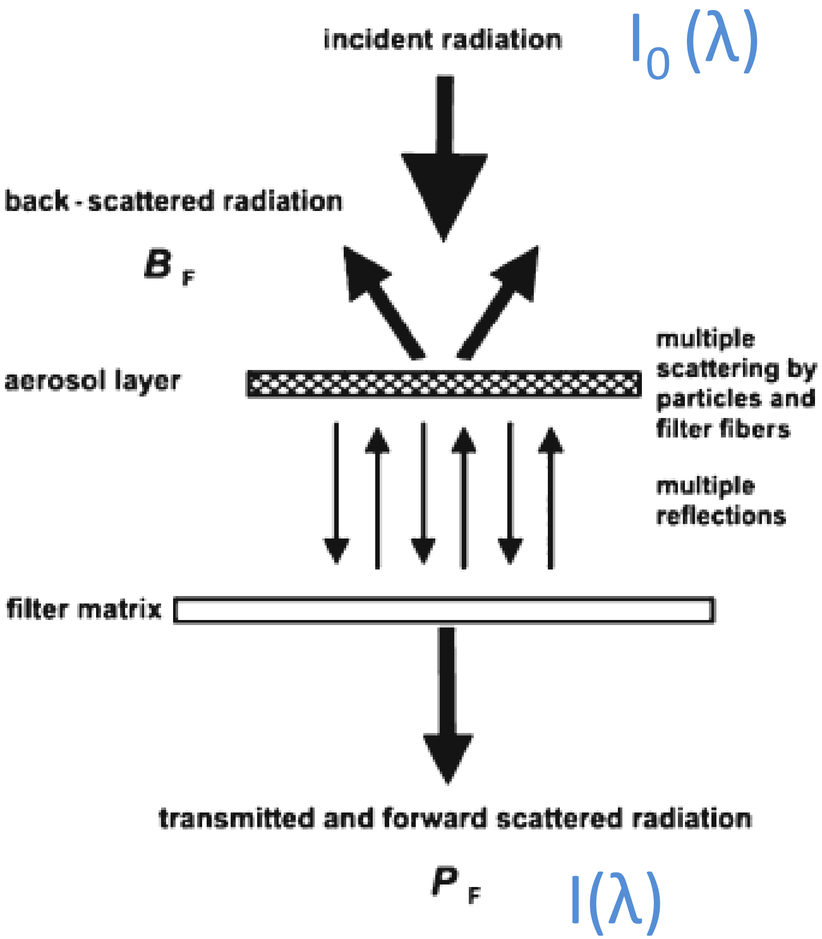
Transmittance

Absorption photometers for real-time application have been available since the 1980s.

<u>Commercial instruments</u>:

- Aethalometer
- Microaethalometer
- PSAP
- MAAP

Filter-based optical methods



$$ATN = \ln \frac{I_0(\lambda)}{I(\lambda)}$$

$$b_{ext.}(\lambda) = \frac{A}{Q} \frac{\Delta ATN(\lambda)}{\Delta t}$$

A: filter area where particles deposit
Q: flow rate of particle laden-air
λ: radiation wavelength

$$b_{ext.} = b_{abs,air} + b_{abs,filter} + b_{abs,part.} + b_{scat,air} + b_{scat,filter} + b_{scat,part.}$$

Filter-based optical methods

Corrections

Algorithms for correcting artefactual enhancement of light absorption by filter-loading, back-scattering, and multiple scattering caused by PM and the filter in connection with aethalometers and PSAP.

The multi -angle absorption photometer (MAAP) is the only real-time absorption photometer that corrects for these artefacts by design.

Filter-based optical methods

Conversion of aerosol light absorption coefficient into light-absorbing carbon mass concentration (BC):

$$eBC(\lambda) = \frac{b_{abs,part}}{\sigma_\lambda}$$

<u>ASSUMPTIONS</u>

- BC is the only absorbing species
- The relationship is linear (ATN<75)

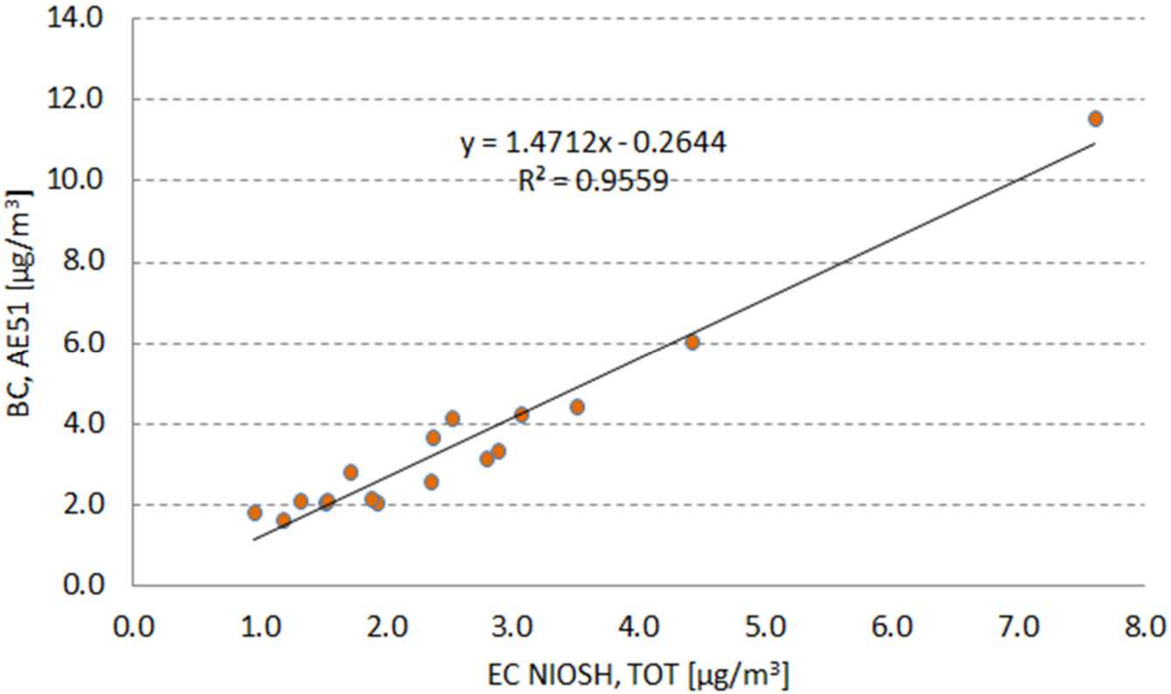
σ_λ: mass-specific absorption cross section

It varies significantly in time and space depending upon source emissions, transformation during transport (Bond and Bergstrom, 2006).

It is determined by an independent method; use of a reference material

Filter-based optical methods

A site-specific σ_λ (18.39 m^2g^{-1}) was calculated by using collocated EC sampling



Scatterplot comparison of 24-h values of BC (AE51) and EC (TOT) mass concentrations conducted at Sítio Cercado (Curitiba, BR).

Terminology for carbonaceous particles

Equivalent black carbon (eBC): A number of commercial instruments that measure the absorption coefficient of absorbing particles derive a mass concentration of BC using a conversion constant referred to as a mass absorption coefficient (σ).

Elemental carbon (EC): Component of the carbonaceous particles that is thermally stable in an inert atmosphere up to 4000 K. It can only be oxidized at T>340°C. EC can be derived from evolved gas analyzer (EGA) measurements, aerosol mass spectroscopy, and Raman spectroscopy measurements.

Organic carbon (OC): Component of carbonaceous particles where the carbon molecules are chemically combined with hydrogen and other elements like oxygen, sulfur, etc. OC can be derived from several different methods and is also an operational definition for EGA measurements.

Refractory black carbon (rBC): The carbon mass derived from laser induced incandescence (LII) is referred to as refractory black carbon since it is derived by measuring the thermal emission of the carbon component of the particle that absorbs the laser energy.

Lack et al., 2014

References

Bond et al., 2013. Bounding the role of black carbon in the climate system: A scientific assessment, J. Geophys. Res., 118, 5380–5552, doi:10.1002/jgrd.50171

Bond & Bergstrom, 2006. Light absorption by carbonaceous particles: an investigative review. Aerosol Sci. Technol., 40, 27-67.

Lack et al., 2014. Characterizing elemental, equivalent black, and refractory black carbon aerosol particles: a review of techniques, their limitations and uncertainties, Anal. Bioanal. Chem., 406, 99-122

Petzold et al., 2013. Recommendations for the interpretation of "black carbon" measurements, Atmos. Chem. Phys., 13, 8365–8379.

THANK YOU!

ATMOSPHER
Laboratory for Urban Air Pollution and Climate

www.atmospher.org

E-mail: patriciak@utfpr.br.edu