Any Colour as long as it is Black

An additional AQ metric that needs to be better defined

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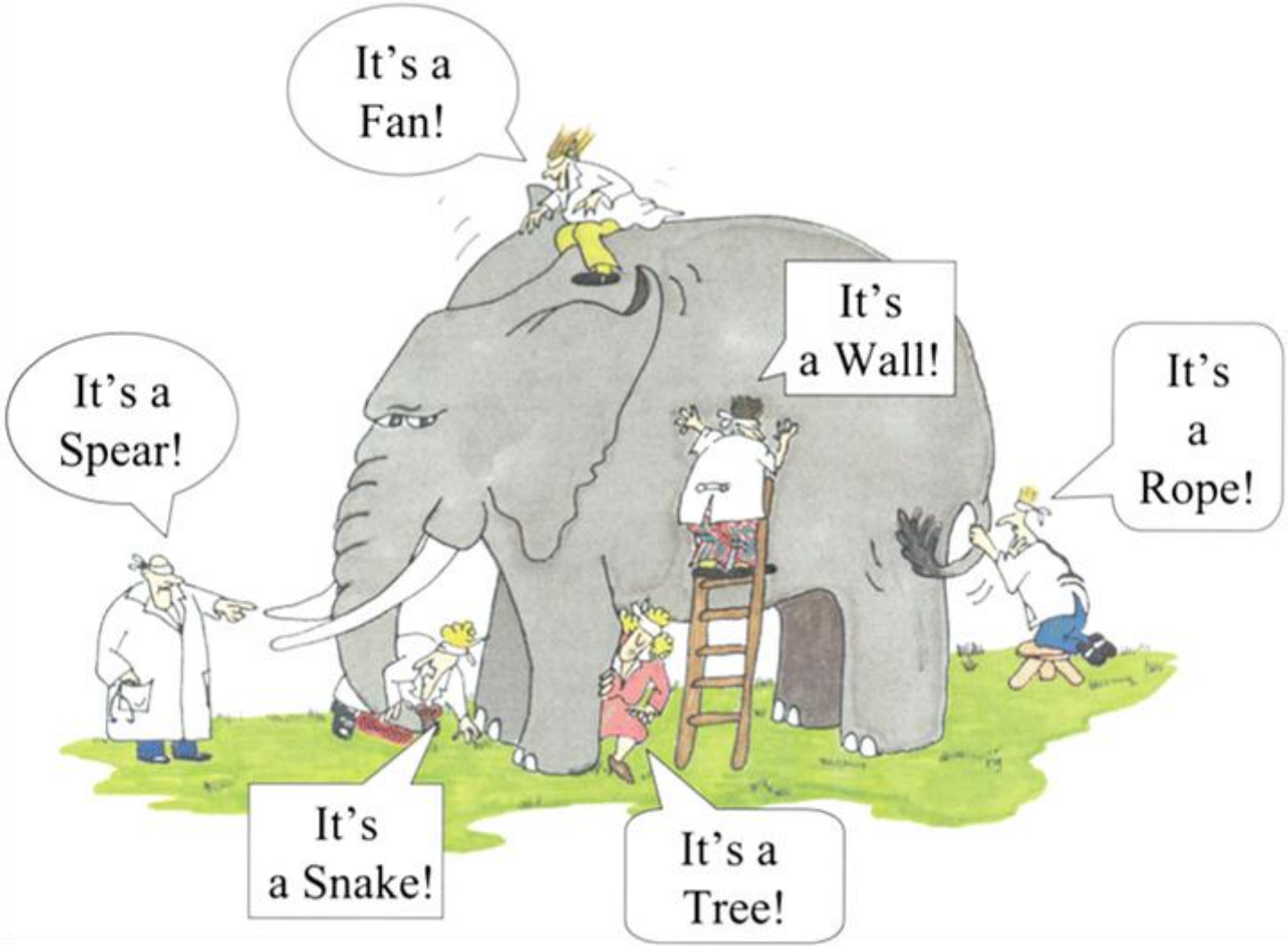
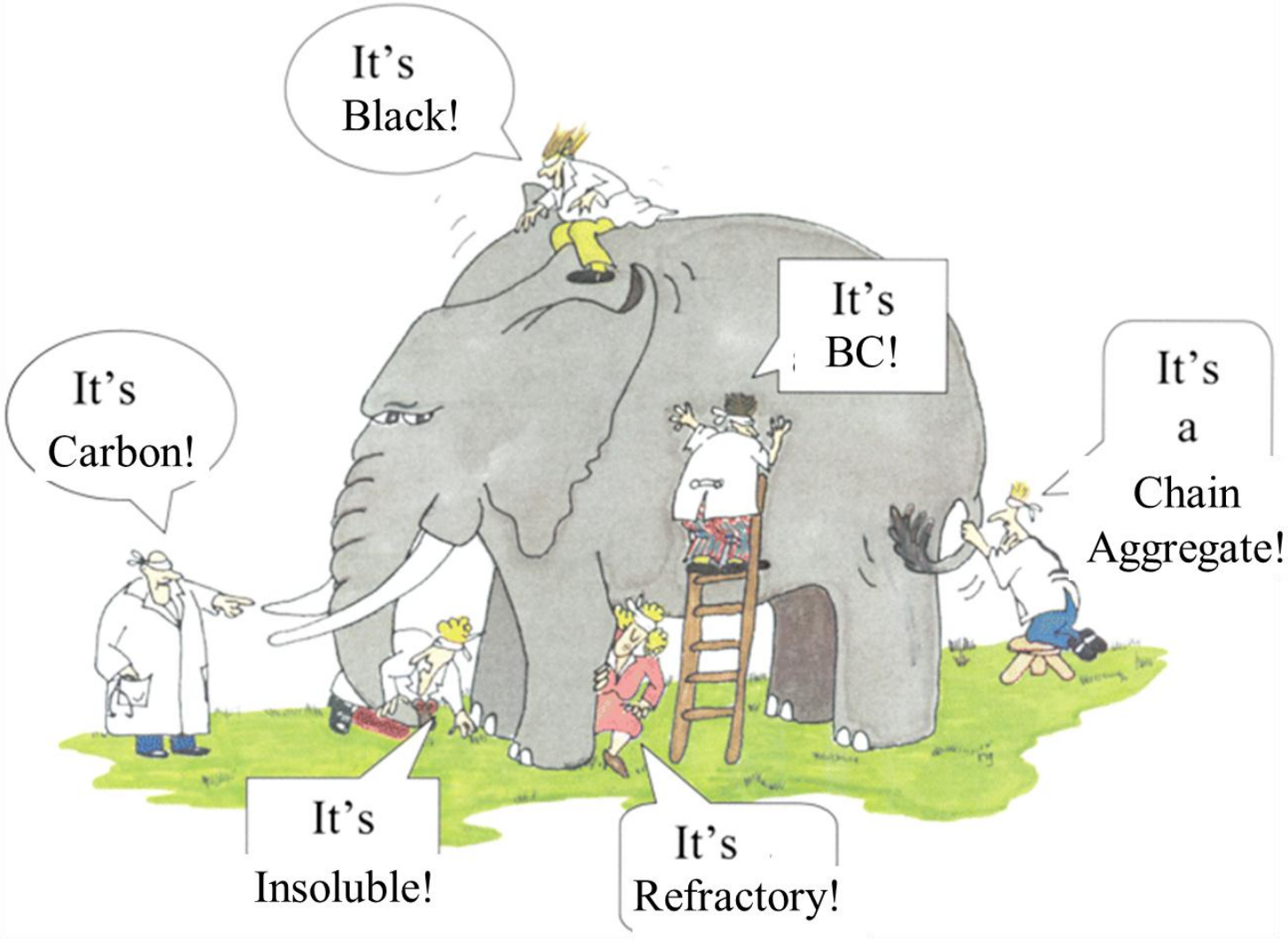
Blind Men and the Elephant



Interpreting “BC” Measurements



What is Black Carbon?

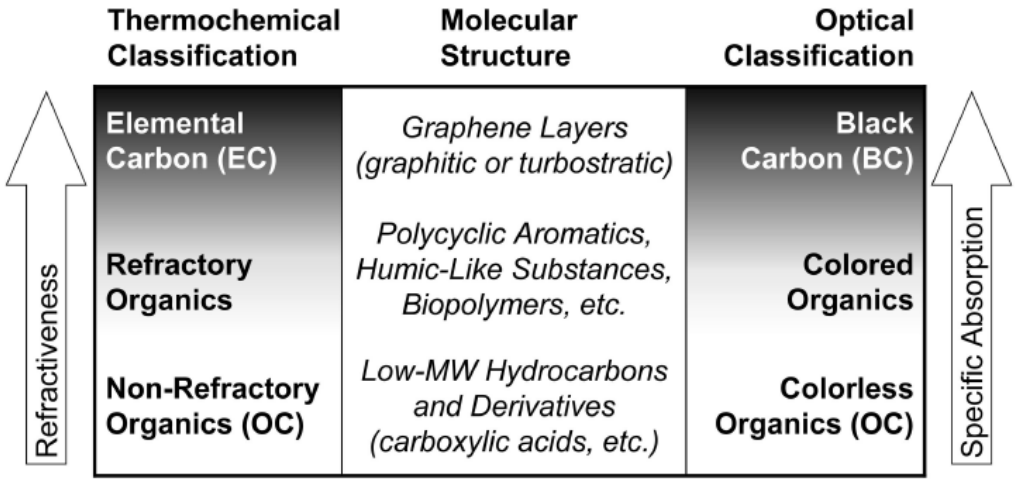
Black carbon (BC) is carbon that is black.
The formation process is excluded from this definition because of the variety of potential processes. While BC is mostly formed in incomplete combustion, it can be a product of pyrolysis of carbonaceous matter, dehydration of sugar, or heating of wood in an oxygen-free atmosphere

Elemental carbon (EC) is formally defined as a substance containing only carbon. The formal term "elemental carbon" refers to a set of materials with different optical and physical properties instead of a given material with well-defined properties. Examples of "true" EC are diamond, carbon nanotubes, graphite or fullerenes.

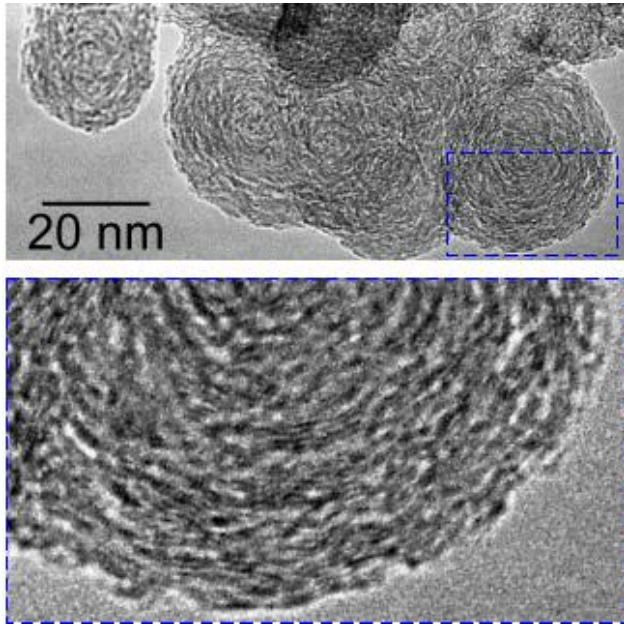
What is Black Carbon?

Strict definitions are not particularly useful in practice, because

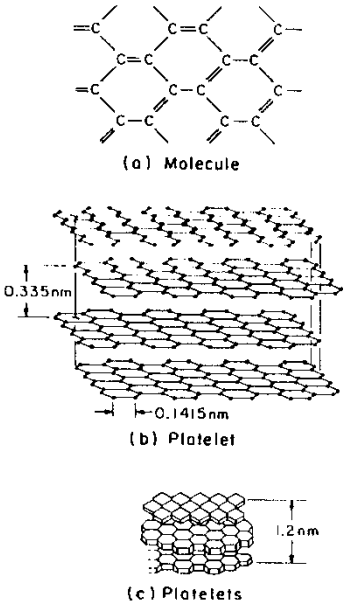
- carbonaceous matter appears in atmospheric aerosols under no circumstances as pure matter;
- it occurs as a highly variable mixture of different carbonaceous compounds with different material properties.



Classification and molecular structure of carbonaceous aerosol components (Pöschl, Anal Bioanal Chem 2003)



Delhaye, 2009



Ogren & Charlson 1983

Light-absorbing aerosol components

VIS + IR	black carbon brown carbon
"green"	Fe_2O_3 , mineral dust
near IR	H_2O
	$(NH_4)_2 SO_4$

In the VIS, only graphitic-like black carbon and refractory organics (brown carbon) absorb light efficiently.

In the graphite lattice, a two-dimensional free electron gas can interact almost perfectly with the electro-magnetic radiation.

What is Black Carbon?

Defined by five essential characteristics

- Composition
- Morphology
- Volatility
- Solubility
- Light absorption

What is Black Carbon?

Carbonaceous particulate matter

- a high fraction of which is sp^2-bonded carbon

Consists of aggregates of spherules

- Individually, from <10 to (typically) 50 nm in diameter

Refractory

Insoluble in water

Strongly absorbs light at all visible wavelengths

- when freshly emitted, has a mass absorption efficiency of at least 5 $m^2\ g^{-1}$ at the mid-visible wavelength of 550 nm

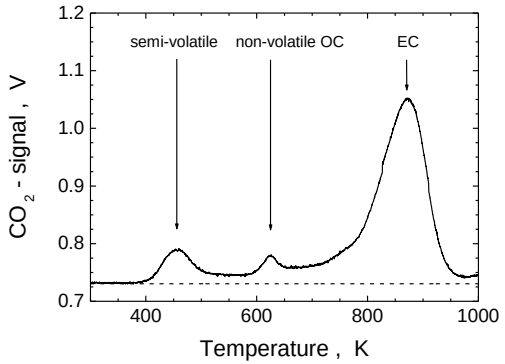
Property	Characteristics	Consequences
Microstructure	graphitic-like structure containing a high fraction of sp^2-bonded carbon atoms	low chemical reactivity in the atmosphere; slow removal by chemical processes; strong optical absorption
Morphology	aggregates consisting of small carbon spherules of < 10 to approx. 50 nm in diameter	high specific surface area; high capacity for sorption of other species
Thermal stability	refractory material with a volatilization temperature near 4000K; gasification is possible only by oxidation at T > 340°C	high stability in the atmo-sphere; longer atmospheric residence time

Property	Characteristics	Consequences
Solubility	insoluble in organic solvents including methanol and acetone, in water, and in the other components of the atmospheric aerosol	Slow removal by clouds and precipitation, unless coated with water-soluble compounds; longer atmospheric residence time
Light absorption	uniformly absorbing in the spectral range of visible light; characterized by a significant, non-zero and wavelength-independent imaginary part of the refractive index over VIS and NIR spectral regions	Reduction of the albedo of clouds, snow, and ice; atmospheric heating; surface cooling – all of which lead to effects on solar radiation and climate

"BC" Measurement Methods

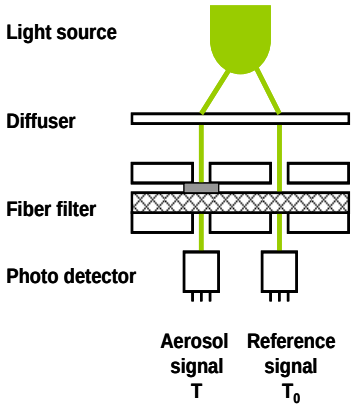
Evolved Carbon

- CO_2 evolved from thermal or thermo-optical methods: IMPROVE / EUSAAR
- BC properties: composition, thermal stabil.



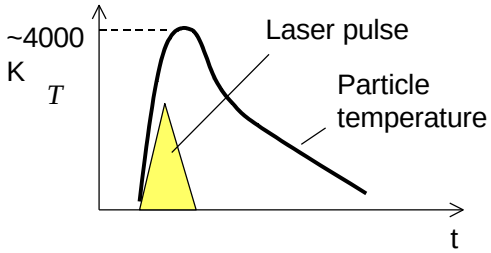
Light Absorption

- Filter-based: Aethalometer, PSAP, MAAP, COSMOS
- In situ: photo-acoustic, ext. minus scat.
- BC properties: light absorption



Laser Incandescence

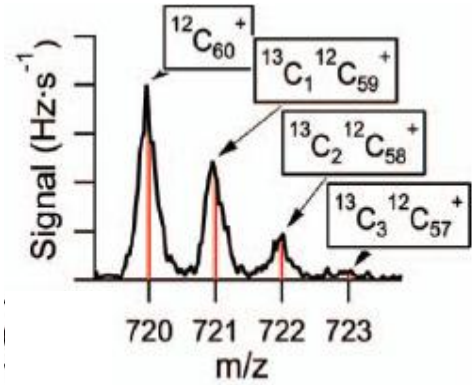
- Laser heating of particles, e.g., SP2, LII
- BC Properties: refractory, composition



"BC" Measurement Methods

Aerosol Mass Spectrometry

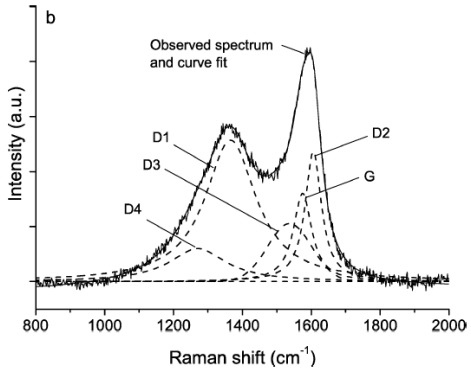
- Vaporization and detection of carbon ion clusters in mass spectra: ATOFMS, SP-AMS
- BC properties: composition



Onasch et al., AS&T 2012

Raman Spectrometry

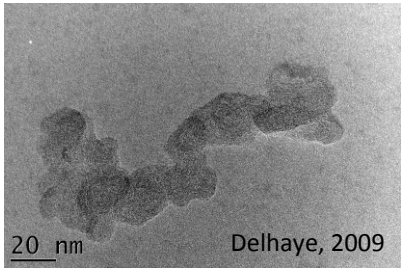
- Detection of graphite-like ordered and disordered carbon
- BC properties: graphite-like microstructure



Ivleva et al., AS&T 2007

Electron microscopy

- Detection of particle microstructure and morphology, e.g. TEM
- BC properties: morphology



Recommended Terminology

Black carbon (BC) *is a useful* ***qualitative description*** *when referring to light-absorbing carbonaceous substances in atmospheric aerosol; however, for quantitative applications the term requires clarification of the underlying determination.*

In the absence of a method for uniquely determining the mass of BC, the term "BC" should be used as a qualitative and descriptive term when referring generally to material that shares some of the characteristics of BC in particular its carbonaceous composition combined with its light-absorbing properties.

Recommended Terminology

Equivalent black carbon (EBC) *should be used instead of black carbon for data derived from* ***optical absorption methods****. It is recommended to report the optical measurements* ***primarily as light absorption coefficient****, and secondarily as EBC, together with a suitable mass absorption coefficient (MAC) for the conversion of light absorption coefficient into mass concentration.*

Refractory black carbon (rBC) *should be used instead of black carbon for measurements derived from* ***incandescence methods****.*

Elemental carbon (EC) *should be used instead of black carbon for data derived from methods that are specific to the* ***carbon content*** *of carbonaceous matter (evolved carbon, aerosol mass spectrometry, Raman spectroscopy).*

Recommended Terminology

Soot *is a useful* ***qualitative description*** *when referring to carbonaceous particles formed from incomplete combustion.*

The term soot generally refers to the source mechanism of incomplete combustion rather than to a material property.

This term is appropriate to and widely used in the research field on the formation of carbonaceous particles in combustion processes and on the emission of particulate matter from combustion sources.

Since atmospheric research usually treats mixed and aged particles instead of freshly emitted exhaust particles, the recommendation is to avoid using this term for atmospheric aerosol.

WMO/GAW Scientific Advisory Group for Aerosols

GAW SAG-Aerosol Members

- John A. Ogren (Chairman), Urs Baltensperger, Angela Benedetti, Markus Fiebig, Thomas Holzer-Popp, Stefan Kinne, Paolo Laj, Shao-Meng Li, Gelsomina Pappalardo, Andreas Petzold, Nobuo Sugimoto, Christoph Wehrli, Alfred Wiedensohler, Xiao-Ye Zhang
- SAG website: http://gaw.tropos.de/index.html
- Comments and questions can be sent to sag-aero@tropos.de
- Petzold, A., et al., Recommendations for the interpretation of "black carbon" measurements, accepted for pub. in ACPD