

Recommendations for Interpretation of "Black Carbon" Measurements

John A. Ogren

**Chairman, WMO/GAW Scientific Advisory Group for Aerosols
National Oceanic and Atmospheric Administration
Earth System Research Laboratory
Global Monitoring Division
Boulder, Colorado, USA**



GAW SAG-Aerosol Members

- John 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
- Manuscript under discussion at <http://www.atmos-chem-phys-discuss.net/13/9485/2013/acpd-13-9485-2013.html>



What are the Issues?

- **Black carbon (BC) has important effects on climate and health**
 - Recently identified as #2 most important climate forcing agent (+1.1 W m⁻², 90% bounds +0.17 to +2.1 W m⁻², Bond et al., 2013).
 - Associated with asthma and other respiratory problems, heart attacks and lung cancer.
- **BC is poorly defined in the scientific literature**
 - Carbonaceous matter does not appear in atmospheric aerosols as a pure substance.
 - Measurements may refer to the same quantity with different names, or to different quantities with the same name.
- **BC measurements depend on the method used**
 - Current methods respond to different properties of BC.
 - Correlations between methods are frequently high, but relationships vary among sites, seasons and aerosol types.

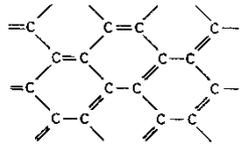


What is Black Carbon?

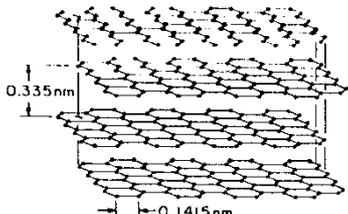
Nanometer scale



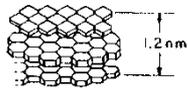
Meter scale



(a) Molecule

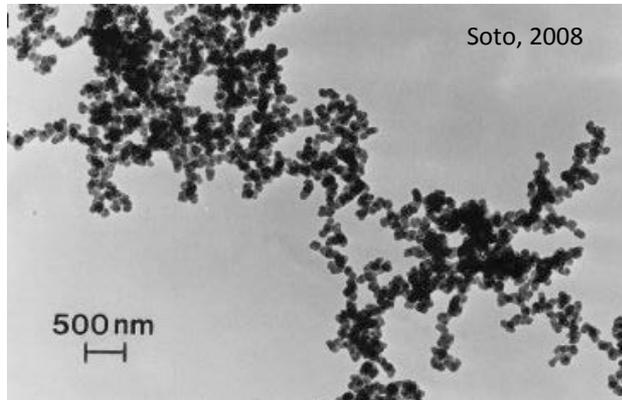
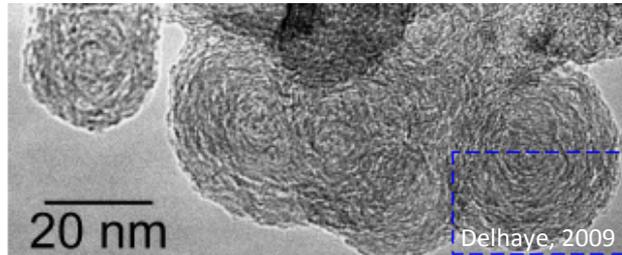


(b) Platelet



(c) Platelets

Ogren & Charlson 1983



What is Black Carbon?

- **Defined by five essential characteristics**
 - Composition
 - Morphology
 - Volatility
 - Solubility
 - Light absorption

Property	Characteristics	Consequences
Composition	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, each typically 10-50 nm diameter	high specific surface area; high capacity for sorption of other species
Volatility	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



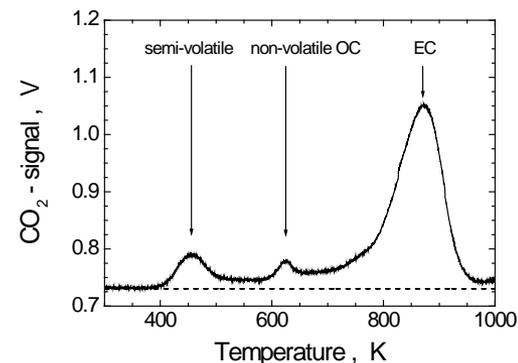
Property	Characteristics	Consequences
Solubility	insoluble in water, in organic solvents including methanol and acetone, and in the other components of the atmospheric aerosol	Slow removal by clouds and precipitation, unless coated with water-soluble compounds; longer atmospheric residence time
Light 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

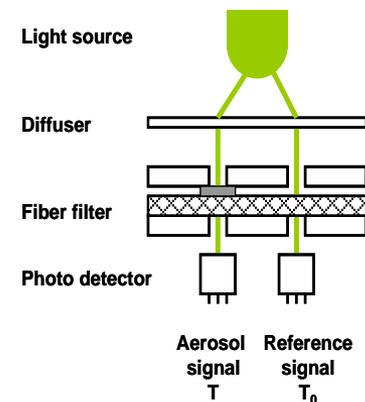
Evolved Carbon

- CO₂ evolved from thermal or thermo-optical methods: IMPROVE / EUSAAR
- BC properties: composition, volatility



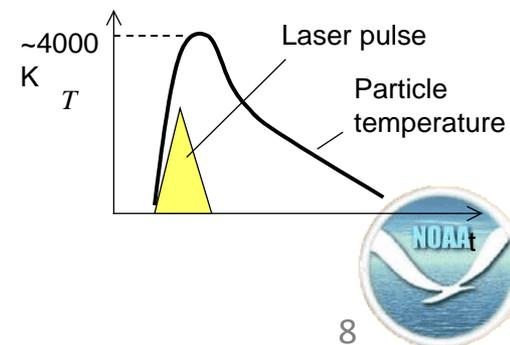
Light Absorption

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



Laser Incandescence

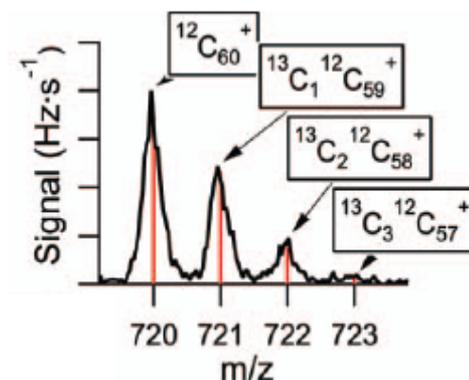
- Laser heating of particles, e.g., SP2, LII
- BC Properties: volatility, composition



“BC” Measurement Methods

Aerosol Mass Spectrometry

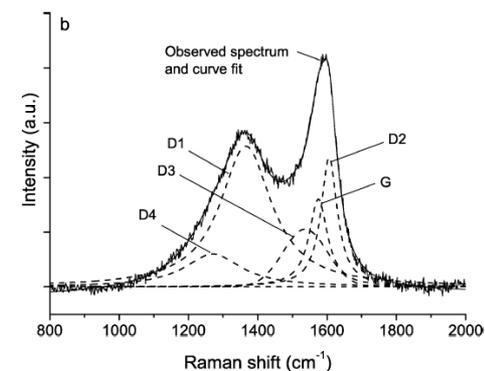
- Vaporization and detection of carbon ion clusters in mass spectra: ATOFMS, SP-AMS
- BC properties: composition



Onasch et al., AS&T 2012

Raman Spectrometry

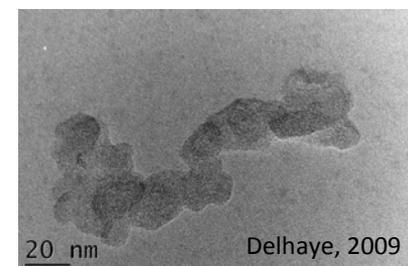
- Detection of graphite-like ordered and disordered carbon
- BC properties: composition



Ivleva et al., AS&T 2007

Electron microscopy

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



Recommended Terminology

- **No current method combines all five essential characteristics of BC**
- **Consequently, no current method can justifiably claim to provide a quantitative measurement of BC**
- **Recommendations**
 - Use “BC” as a qualitative term referring to any of the quantitative methods
 - Use terms associated with the measurement methods when reporting quantitative results

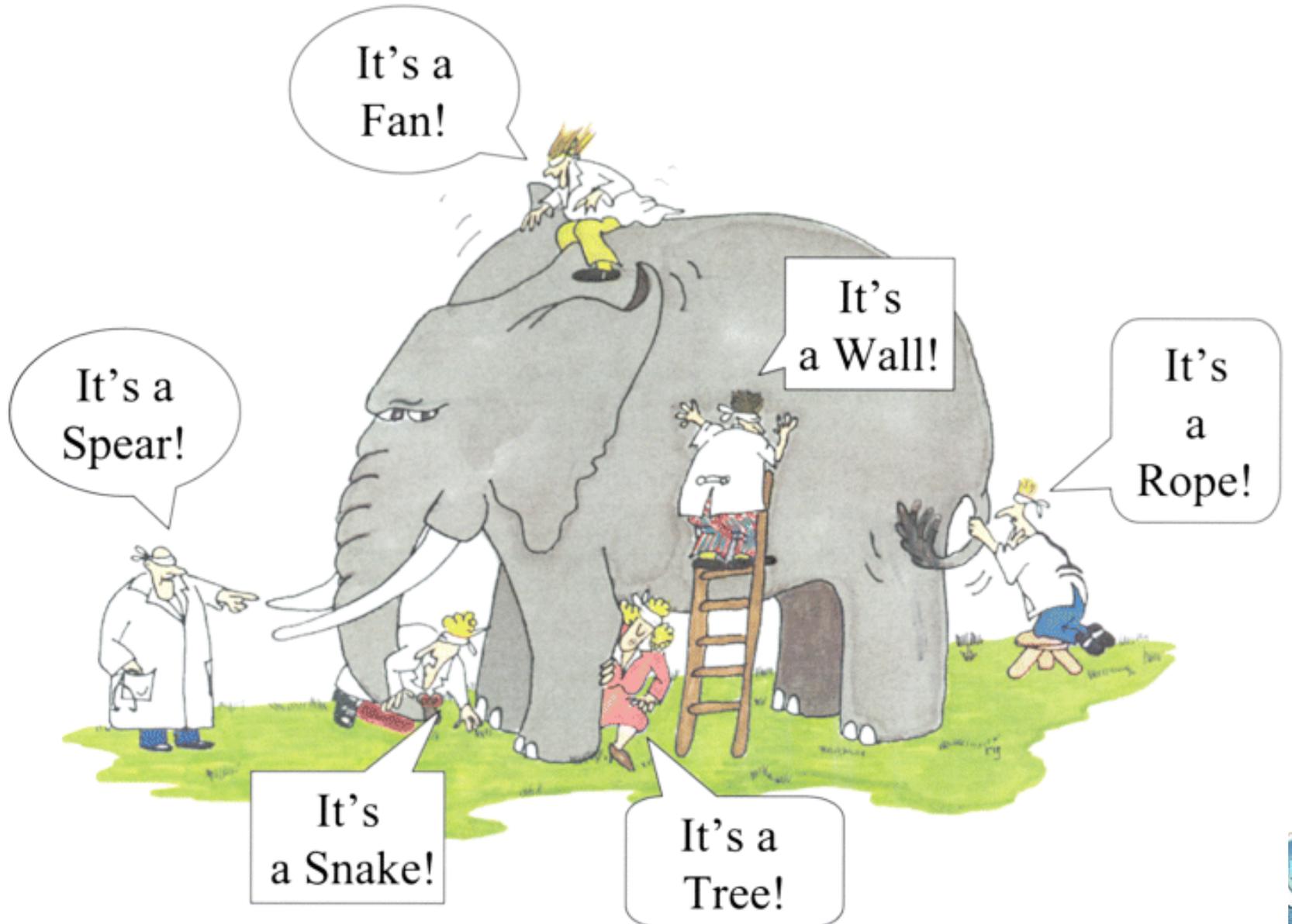


Recommended Terminology

- **Equivalent black carbon (EBC)**
 - Data derived from *optical absorption methods*.
 - Report the optical measurements primarily as light absorption coefficient, and secondarily as EBC, along with the mass absorption efficiency used to convert absorption to EBC.
- **Refractory black carbon (rBC)**
 - Data derived from *incandescence methods*.
- **Elemental carbon (EC)**
 - Data derived from methods that are specific to the *carbon content* of carbonaceous matter (evolved carbon, aerosol mass spectrometry, Raman spectroscopy).



Blind Men and the Elephant



Interpreting "BC" Measurements

