Recommendations for Interpretation of "Black Carbon" Measurements

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- 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

20 nm

Delhaye, 2009

Soto, 2008

500 nm

Ogren & Charlson 1983

Delhaye, 2009

Soto, 2008

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What is Black Carbon?

• Defined by five essential characteristics
  – Composition
  – Morphology
  – Volatility
  – Solubility
  – Light absorption
<table>
<thead>
<tr>
<th>Property</th>
<th>Characteristics</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>graphitic-like structure containing a high fraction of sp²-bonded carbon atoms</td>
<td>low chemical reactivity in the atmosphere; slow removal by chemical processes; strong optical absorption</td>
</tr>
<tr>
<td>Morphology</td>
<td>aggregates consisting of small carbon spherules, each typically 10-50 nm diameter</td>
<td>high specific surface area; high capacity for sorption of other species</td>
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<td>Volatility</td>
<td>refractory material with a volatilization temperature near 4000K; gasification is possible only by oxidation at T &gt; 340°C</td>
<td>high stability in the atmosphere; longer atmospheric residence time</td>
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<tr>
<td>Solubility</td>
<td>insoluble in water, in organic solvents including methanol and acetone, and in</td>
<td>Slow removal by clouds and precipitation, unless coated with water-soluble</td>
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<tr>
<td></td>
<td>the other components of the atmospheric aerosol</td>
<td>compounds; longer atmospheric residence time</td>
</tr>
<tr>
<td>Light absorption</td>
<td>uniformly absorbing in the spectral range of visible light; characterized by a</td>
<td>Reduction of the albedo of clouds, snow, and ice; atmospheric heating; surface</td>
</tr>
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<td></td>
<td>significant, non-zero and wavelength-independent imaginary part of the refractive</td>
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<td>index over VIS and NIR spectral regions</td>
<td>cooling – all of which lead to effects on solar radiation and climate</td>
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“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

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

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

It’s a Fan!

It’s a Spear!

It’s a Wall!

It’s a Rope!

It’s a Snake!

It’s a Tree!
Interpreting “BC” Measurements

It's Black

It's BC!

It's a Chain Aggregate

It's Carbon

It's Insoluble

It's Refractory