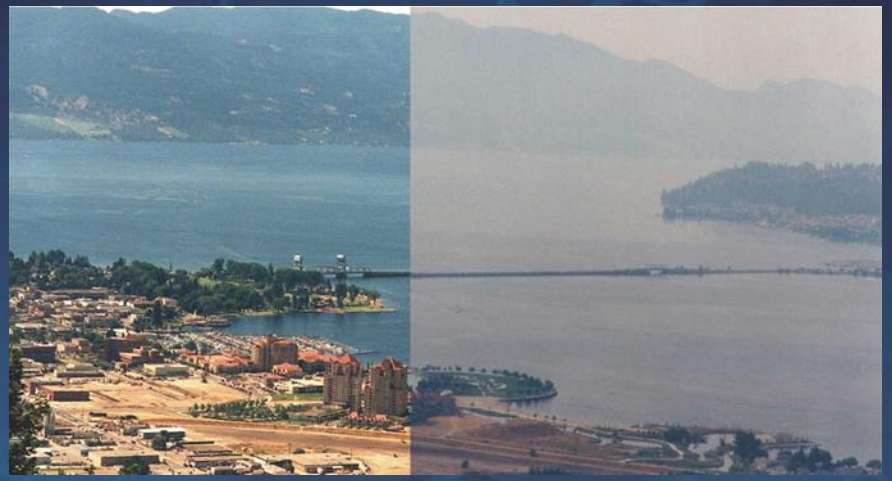
NRC·CNRC



Black Carbon: Measurement Issues

Greg Smallwood

CCAC Marine Black Carbon Emissions Workshop: Identifying Research Gaps

9-10 Sep 2014 Ottawa, ON, Canada

What Needs to be Measured?

- health and environmental researchers and policymakers are asking for more specificity on PM
  - mass and number
  - size and size distribution
  - composition (black carbon, organic carbon, sulphates, nitrates)
  - surface area and surface reactivity
  - optical properties (absorption and scattering)
- BC provides specificity on composition
  - what should be measured for BC?
    - mass
    - number
    - absorption
    - other measurands (size distribution, surface coatings, etc.)?

Measurement Issues (I)

Traceability

- many instruments offer no opportunity for traceability
- filter-based mass can be traceable
  - issues with sensitivity (mass of particulate vs. mass of filter)
  - issues with filter artifacts
    - gaseous adsorption
    - fibre loss
    - less than 100% removal efficiency
  - issues with size cutoff
    - impactors and cyclones do not cut sharply at threshold (i.e. $PM_{2.5}$)
- number concentration can be made traceable
  - ISO/FDIS 27891 - Aerosol particle number concentration -- Calibration of condensation particle counters

Measurement Issues (II)

Reliability and Repeatability

- difficult to establish

Uncertainty

- large uncertainties (can be order of magnitude in number, factor of 2 in mass)

Reference Materials

- airborne particulate RMs don't exist

Representativeness

- all ex-situ methods suffer from sampling issues
  - how representative is the sample at the measurement location of the airborne particulates?
    - losses – diffusion, thermophoretic,impaction,…
    - agglomeration
    - evaporation/condensation

Measurement Issues (III)

Measuring properties with different methods

- most instruments are proprietary
  - each manufacturer implements a different measurement principle
- difficult to intercompare results obtained with different instruments
- example
  - black carbon mass
    - directly measured, or inferred from optical absorption, extinction, or emission measurements

Calibration

- is the instrument calibrated with a standard method?
- what is the uncertainty?

Measurement Issues (IV)

Measuring specific properties with a myriad of interferences

- selectivity
  - how does one measure properties of BC when many other PM components are present?
- sensitivity
  - atmospheric concentrations are often very low (<1 µg/m^3)
- gas composition
  - can be highly variable, especially in engine exhausts
  - can influence measurement
- morphology
  - spherical particles vs. fractal aggregates
- single particle vs. ensemble measurements
- variations over time, elevation, temperature, humidity, sunlight, etc.

Examples of Instruments used to Measure BC: Mass (top row) and Morphology/Size/Number (lower row)

Laser Induced Incandescence

Thermal Optical EC/OC Analyzer

Gravimetric

Centrifugal Particle Mass Analyzer

HR-TEM

Electrostatic Precipitator

Fast Particle Mobility Size Spectrometer

Scanning Mobility Particle Sizer

Condensation Particle Counter

Thank you

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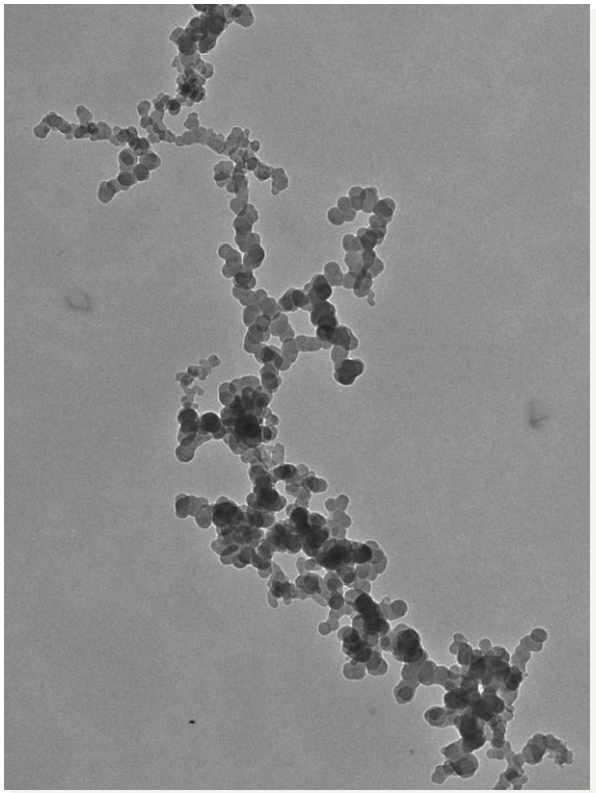
Definition for Black Carbon

"Black Carbon is a distinct type of carbonaceous material that is formed primarily in flames, is directly emitted to the atmosphere, and has a unique combination of physical properties"

- strongly absorbs visible light
- is refractory with a vaporization temperature near 4000 K
- exists as an aggregate of small spheres
- is insoluble in water and common organic solvents



Bond et al., "Bounding the role of black carbon in the climate system: A scientific assessment,"Journal of Geophysical Research – Atmospheres, 118, (2013)