A Low-Cost, High Performance, Industrial Grade Carbon Sensor

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Outline

• Definitions
• Physical and Chemical Characteristics of BC
• Sources of BC
• Motivation for Monitoring Black Carbon
• C-12 Portable Carbon Sensor
• Applications of Low-Cost Carbon Sensors
  – China
  – Grants Pass Oregon
• Summary
What is Black Carbon?

• **BC is a solid pollutant**
  – Byproduct of the incomplete combustion of fossil fuels
  – Byproduct of the incomplete combustion of biomass

• **BC is not a single substance:**
  – A complex array of combustion particulate dominated by $sp^2$ (graphite-like) carbon (~90% by weight), oxygen, hydrogen, and other elements
  – Interacts and evolves with the surroundings
Physical and Chemical Properties of Black Carbon

- Refractory
- Insoluble in water, all organic solvents
- Relatively inert chemically
- Absorbs across the entire NIR-NUV spectrum
- No consensus on calibration standard
- Results are method dependent
Where Does Black Carbon Come From?

- Incomplete combustion of fossil fuels
- Incomplete combustion of biomass
  - Often accompanied with polycyclic aromatic hydrocarbons “PAH”, lower molecular weight organic substances (which are often soluble in organic solvents).
  - Accompanying PAH compounds often have enhanced absorption properties in UV-region
Why is Ambient Monitoring of Black Carbon Important?

- BC a driver of global warming
- BC has been linked to cancer and pulmonary disease
- Urban BC often originates near roadways, factories, industrial processes often in disadvantaged areas.
How is Black Carbon Monitored?

- **Thermo-optical reflectance (TOR) or thermo-optical transmission (TOT)**
  - Sunset Labs OC-EC, Magee TCA
  - Usually lab-based
  - Generally expensive

- **Filter-based optical absorption**
  - MOI BC-1054, BC-1060 Portable Monitor
  - C-12 Low-Cost Carbon Monitor
Met One Instruments C-12 Portable Carbon Sensor
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principle of Operation</td>
<td>Optical attenuation across filter media</td>
</tr>
<tr>
<td>Illumination Wavelength</td>
<td>880 nm standard</td>
</tr>
<tr>
<td></td>
<td>880 nm and 370 nm optional</td>
</tr>
<tr>
<td>Cut Point</td>
<td>TSP (bug screen)</td>
</tr>
<tr>
<td>Sampling Rate</td>
<td>1 LPM</td>
</tr>
<tr>
<td>LDL (2 (\sigma))</td>
<td>&lt; 80 ng/m(^3) (1-minute time scale)</td>
</tr>
<tr>
<td>Communications</td>
<td>USB, Built in CCS+ COMET Cloud Modem 4G LTE</td>
</tr>
<tr>
<td>Input Power</td>
<td>100-240 VAC 50/60 Hz</td>
</tr>
<tr>
<td></td>
<td>Optional Solar Panel</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>6 W</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>-20 C to +50 C</td>
</tr>
<tr>
<td>Weight</td>
<td>7.6 kg</td>
</tr>
<tr>
<td>Size</td>
<td>38.1 x 30.5 x 30.5 cm</td>
</tr>
<tr>
<td>Filter Media</td>
<td>Hygroscopic glass fiber (&gt;1,000 spots/roll)</td>
</tr>
</tbody>
</table>
C-12 China Comparative Test

Hourly BC Comparison 880 nm Illumination

BC Concentration ng/m³

3/12/22 0:00 to 3/19/22 0:00
C-12 China Comparative Test

Hourly BC Comparison 880 nm Illumination

BC Concentration ng/m³

3/12/22 0:00 to 3/19/22 0:00

-1000 to 9000

B19933, B19934, B19932, AE33
Beijing China Test Site
C-12 Grants Pass Oregon Controlled Burn 1-Minute Data

BC Concentration ng/m³

4/2/22 0:00 4/3/22 0:00 4/4/22 0:00

370nm 880nm
Summary

- C-12 output compares well to AE33, base price is around $3500, however
- C-12 retains much of the functionality of more expensive tape-based monitors
- Sensitivity is consistent with other tape-based BC monitors
- C-12 may be easily deployed in a matter of minutes in any area with cellular reception