

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

David Gobeli, Ph.D., Jen Brown, Annie Chen*

Met One Instruments, Incorporated

Grants Pass OR USA

*Beijing Met High-Tech Co., Ltd.

Beijing, PRC

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

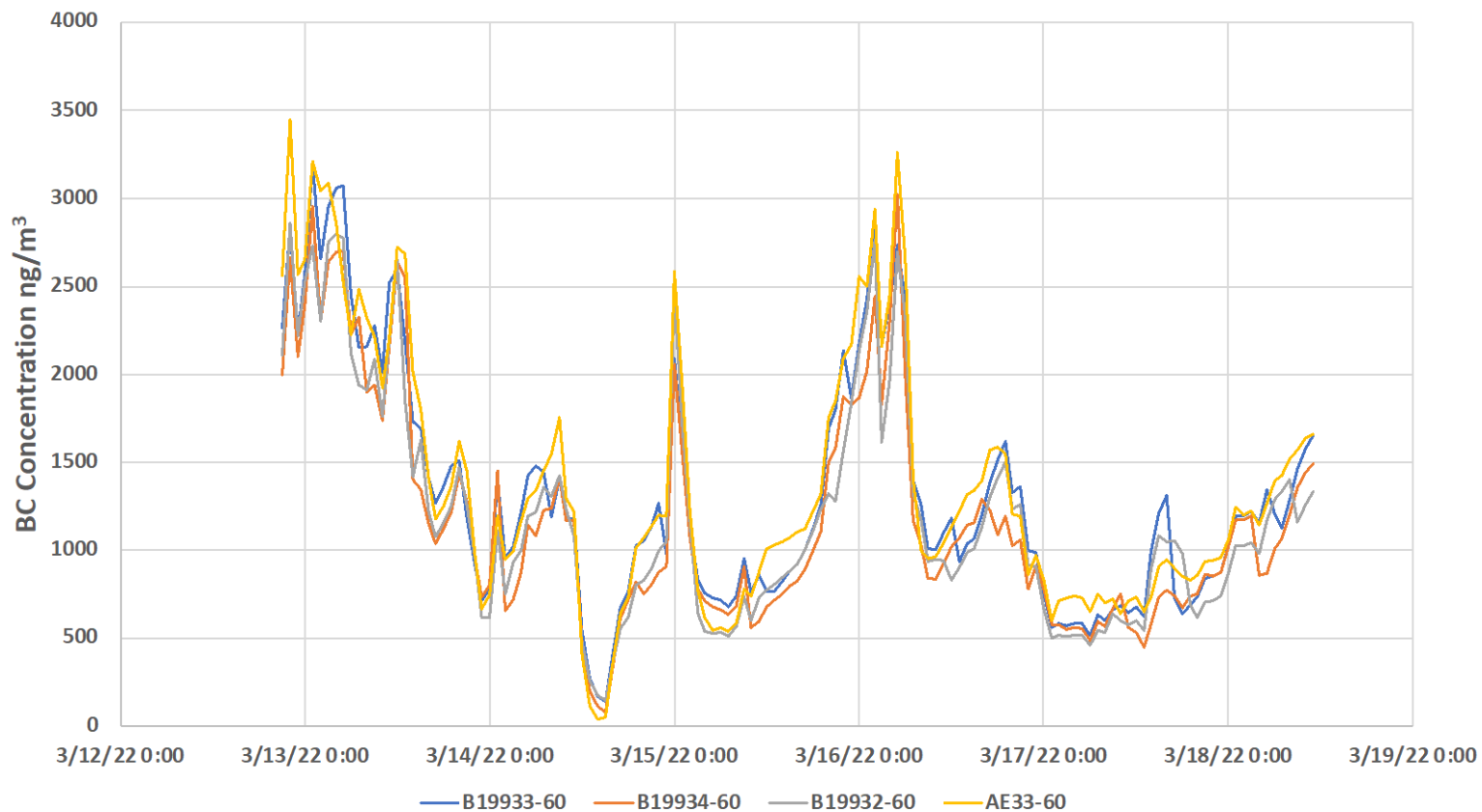
Met One Instruments C-12 Portable Carbon Sensor



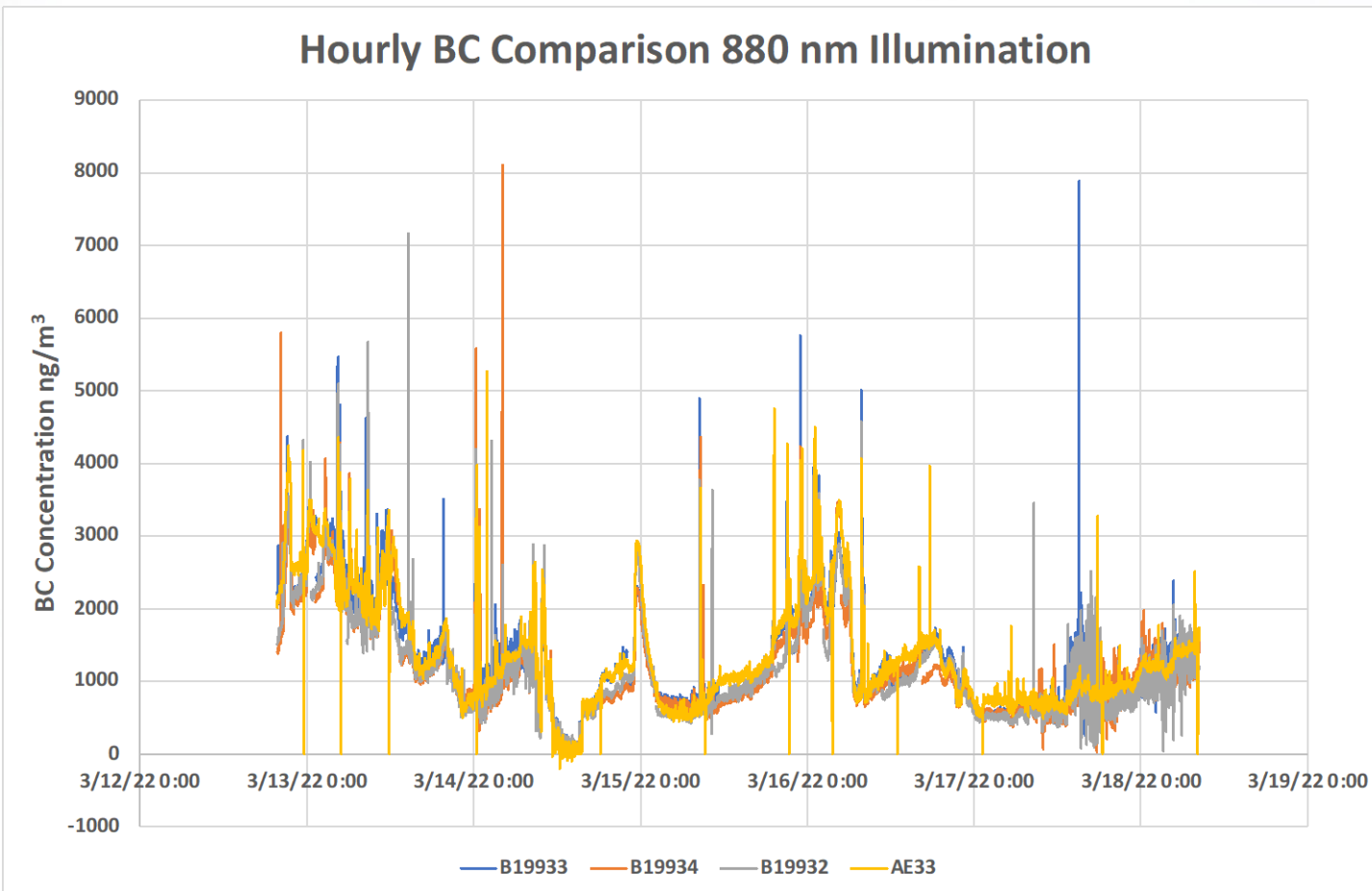
Parameter	Specification
Principle of Operation	Optical attenuation across filter media
Illumination Wavelength	880 nm standard 880 nm and 370 nm optional
Cut Point	TSP (bug screen)
Sampling Rate	1 LPM
LDL (2 σ)	< 80 ng/m ³ (1-minute time scale)
Communications	USB, Built in CCS+ COMET Cloud Modem 4G LTE
Input Power	100-240 VAC 50/60 Hz Optional Solar Panel
Power Consumption	6 W
Operating Temperature Range	-20 C to +50 C
Weight	7.6 kg
Size	38.1 x 30.5 x 30.5 cm
Filter Media	Hygroscopic glass fiber (>1,000 spots/roll)

C-12 China Comparative Test

Hourly BC Comparison 880 nm Illumination



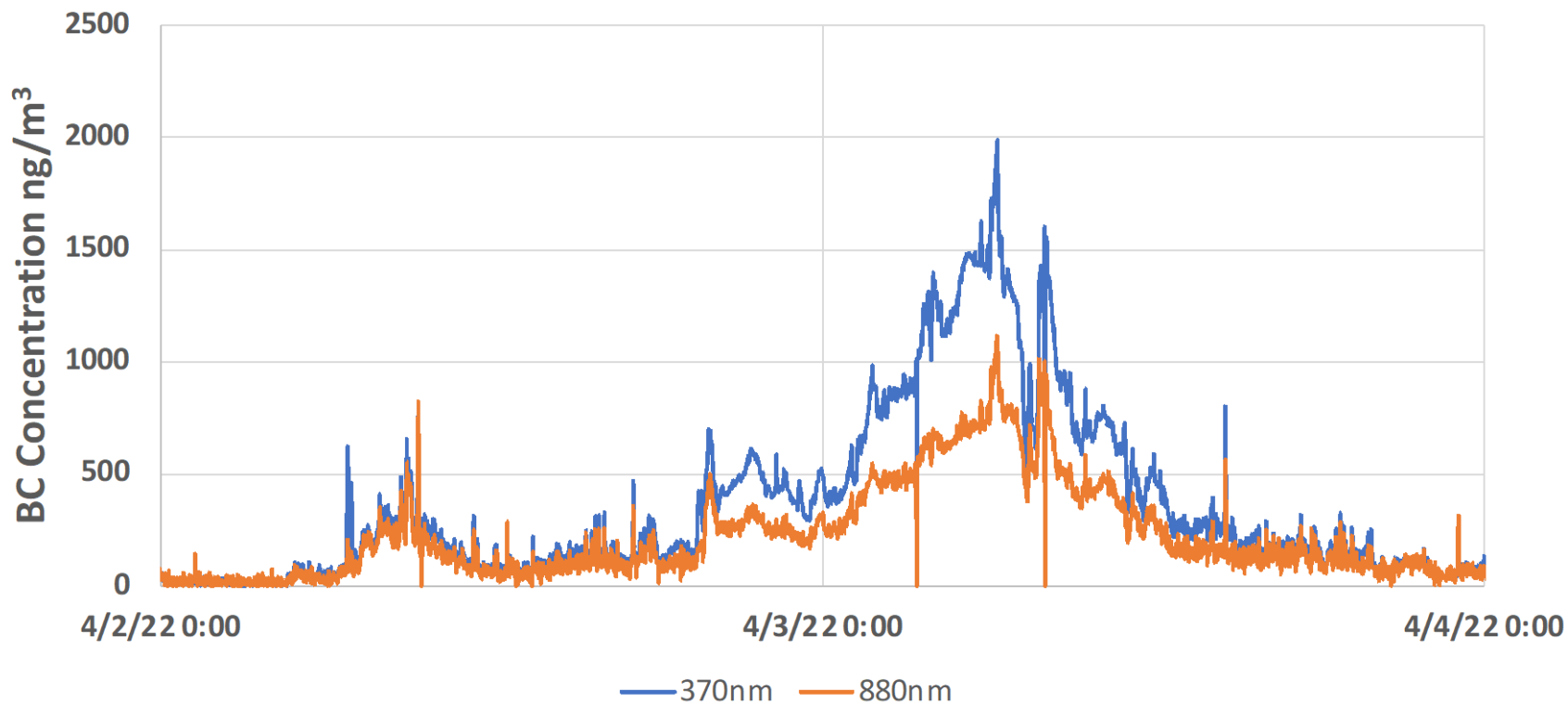
C-12 China Comparative Test



Beijing China Test Site



C-12 Grants Pass Oregon Controlled Burn 1-Minute Data



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