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Contribution and sources of light absorption brown carbon at a suburban site in Guangzhou, China

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Why care about Brown carbon?

- Quantitative prediction of radiative forcing due to aerosol is still challenging.
- Black carbon? Brown carbon (BrC)?
- BrC is an ensemble of light absorbing (colored) organic compounds.

- Particles from **smoldering combustion** can contain substantial amounts of BrC.
- Appears **light brown** to **yellowish**, and not black as would be expected for black carbon.

Sources and chemical compositions of BrC

Both **primary** and **secondary sources:**

- biomass burning, biological aerosols,
- secondary organic aerosol formed from anthropogenic or biogenic precursors.

Several classes of compounds:

- **nitroaromatic compounds**, such as nitrophenols
- **N-heterocyclic compounds**,
- and **quinones**.

BrC studies in Pearl River Delta region

- Light absorption of brown carbon aerosol in the PRD region of China by J.-F. Yuan, et al. Atmos. Chem. Phys., 2016

  BrC contributed 6.3% to 12.1% of the total aerosol light absorption at 405 nm;

  4.1% to 10.0% at 532 nm.

- However, little is known about the **relationship** between the **brown carbon** and **aerosol chemical compositions**.

Sampling site

Sampling period: 7th Nov. 2014 -3rd Jan. 2015

Panyu site:

- About 15 km south of the downtown Guanzhou
- Located at the summit of Dazhengang at ~150 m

Instruments

Aethalometer (AE33):

Seven wavelengths aerosol light absorption

(λ = 370, 470，520, 590, 660, 880 and 950nm)

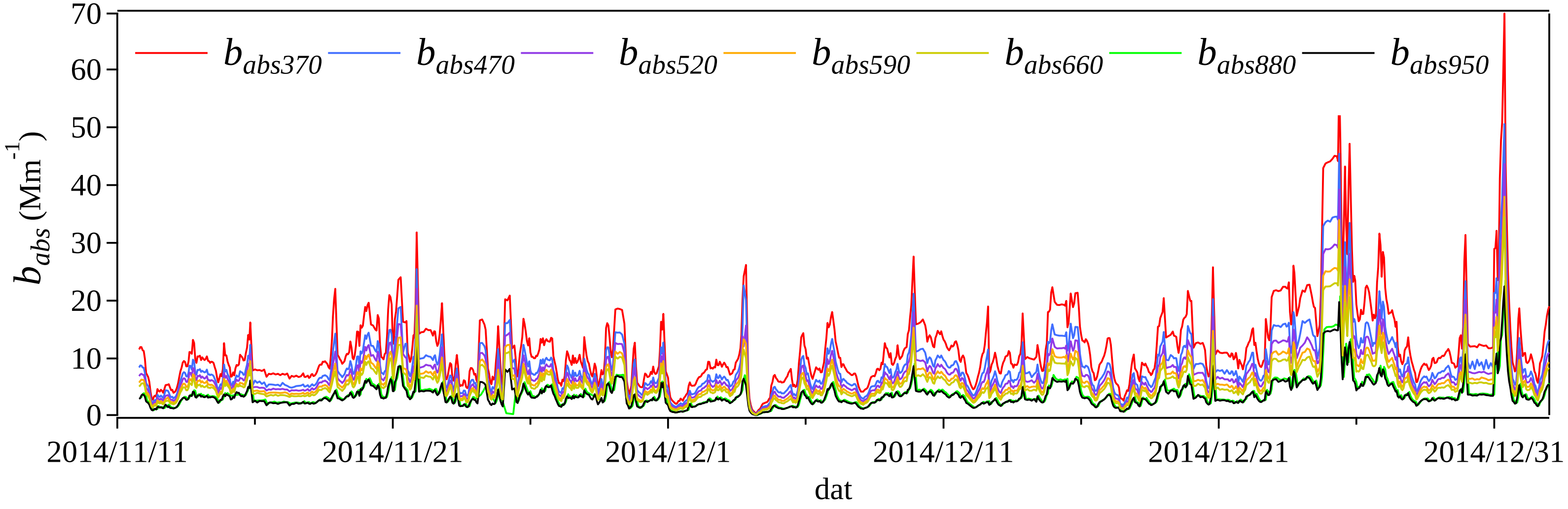
Figure 1. The Aethalometer® Model AE33.

High-resolution Time-of-Flight Aerosol Mass Spectrometer (HR-Tof-AMS):

Organics factors and organic nitrate, CHN,CHON CHOxN groups

Time series of aerosol light absorption at different wavelengths

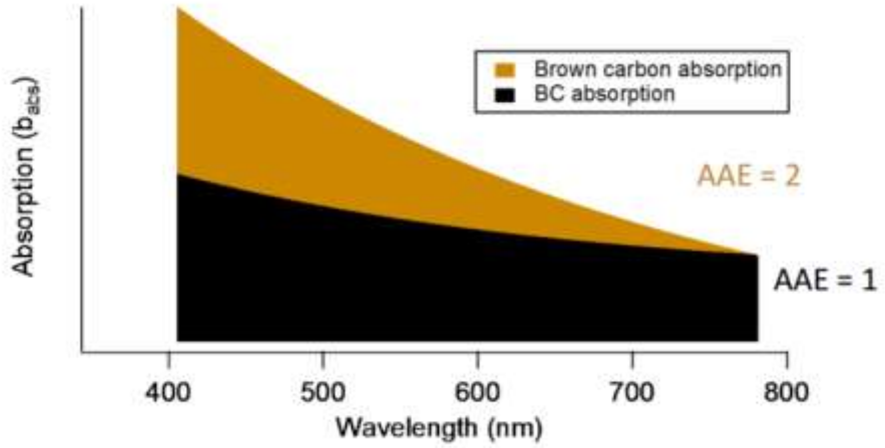
Figure 1. The Aethalometer® Model AE33.



The average absorption was 11.8 Mm^{-1} at 370nm , 8.6 Mm^{-1} at 470 nm, 7.3 Mm^{-1} at 520, 6.3 Mm^{-1} at 590nm, 5.6 Mm^{-1} at 660nm,3.8 Mm^{-1} at 880nm and 3.6 Mm^{-1} at 950nm.

Absorption Angström exponent (AAE)

The basic theory used to describe light absorption properties is the well-known power-law relationship: Abs_{λ}=K*λ^{-AAE}



where Abs_{λ} (unit: Mm^{-1} or M^{-1}) refers to the absorption coefficient of aerosol at wavelength λ (unit: nm). K is a constant.
AAE indicates the wavelength dependence of light absorption.

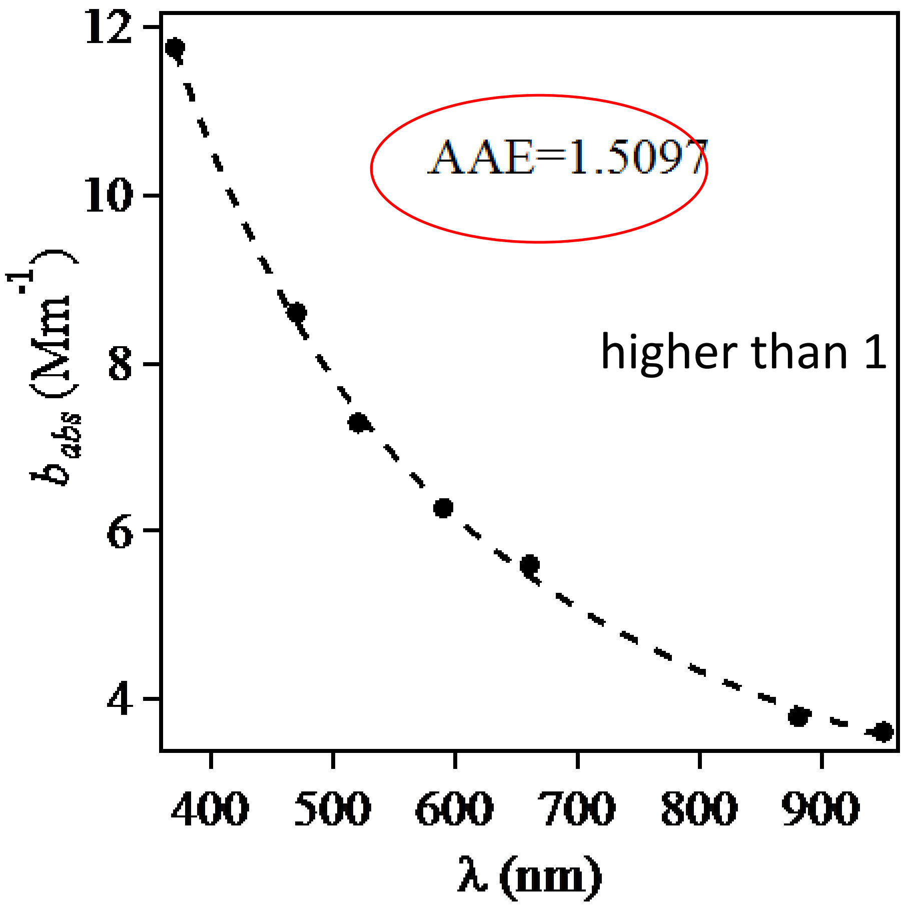
Pure black carbon: AAE ~1;
AAE for brown carbon ≥2, up to 9.7

The presence of BrC will make the absorption stronger at shorter wavelengths:

- BrC mainly absorb light at UV and short-visible wavelengths
- and absorb negligibly at longer wavelength.

Average absorption spectra and AAE

$Abs_\lambda = K * \lambda^{-AAE}$



the presence of brown carbon

Average absorption spectra over 370-950nm wavelength during the whole campaign.

Attribution of aerosol light absorption to BC and BrC

- Power-law relationship Abs_{λ}=K*λ^{-AAE}
- BrC mainly absorb light at UV and short-visible wavelengths and absorb negligibly at longer wavelength.

Absorption at a longer wavelength, at which BrC has negligible or no absorption

Theoretical AAE value for pure black carbon, "1"

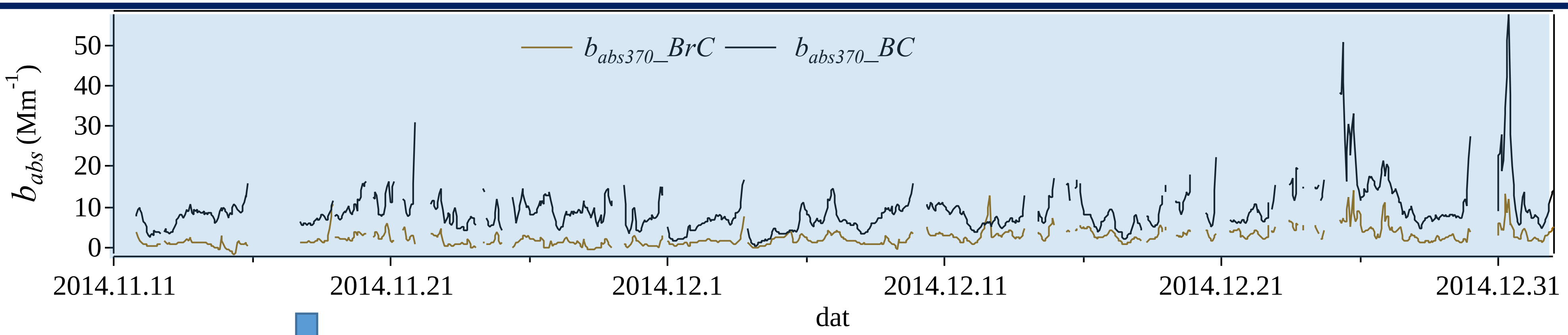
Attributed absorption of BC at a short wavelength.

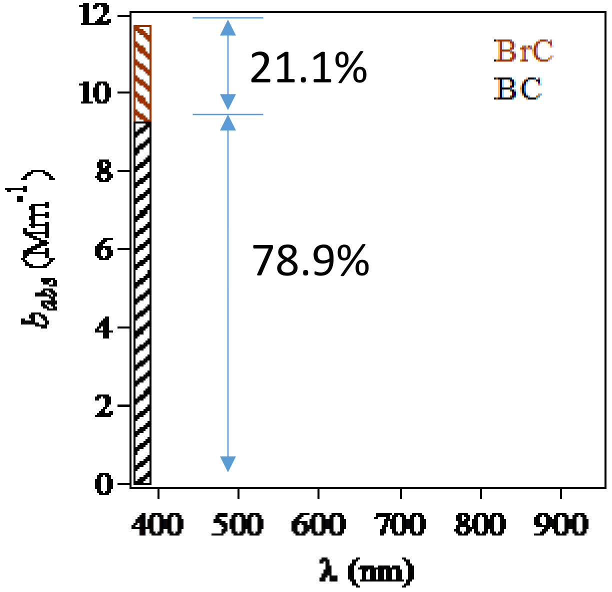
$$BC\_Abs_{\lambda_1} = Abs_{\lambda_2} \times (\lambda_2/\lambda_1)^{AAE_{BC}}$$

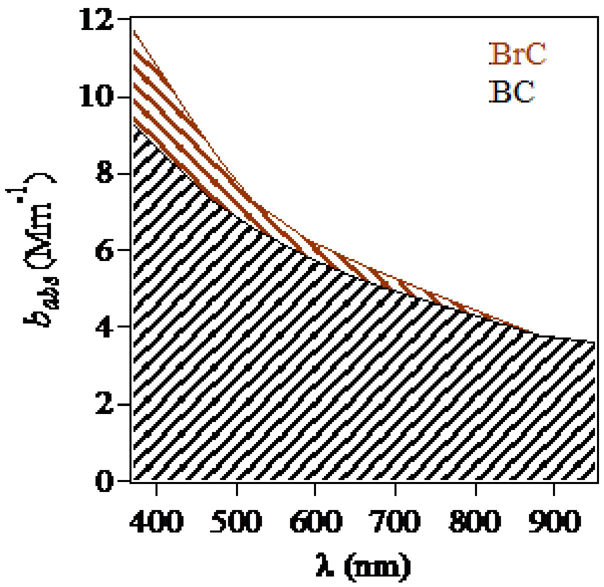
$$BrC\_Abs_{\lambda_1} = Abs_{\lambda_1} - BC\_Abs_{\lambda_1},$$

Attributed absorption of BrC

Contribution of aerosol light absorption to BC and BrC



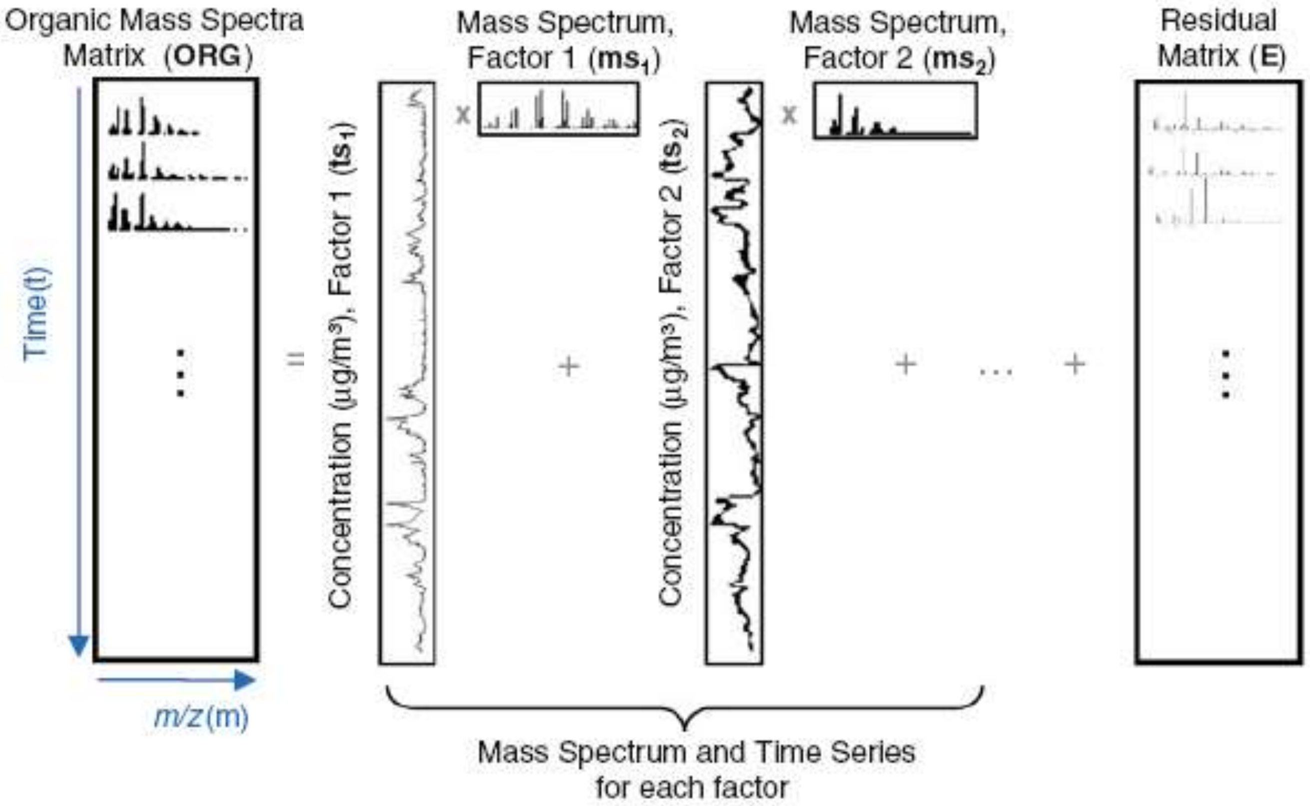




Light absorption contribution due to BrC :
21.1% at 370nm
15.2% at 470nm
9.6% at 520 nm
7.4% at 590nm
and 7.2% at 660 nm

Organic factor analysis

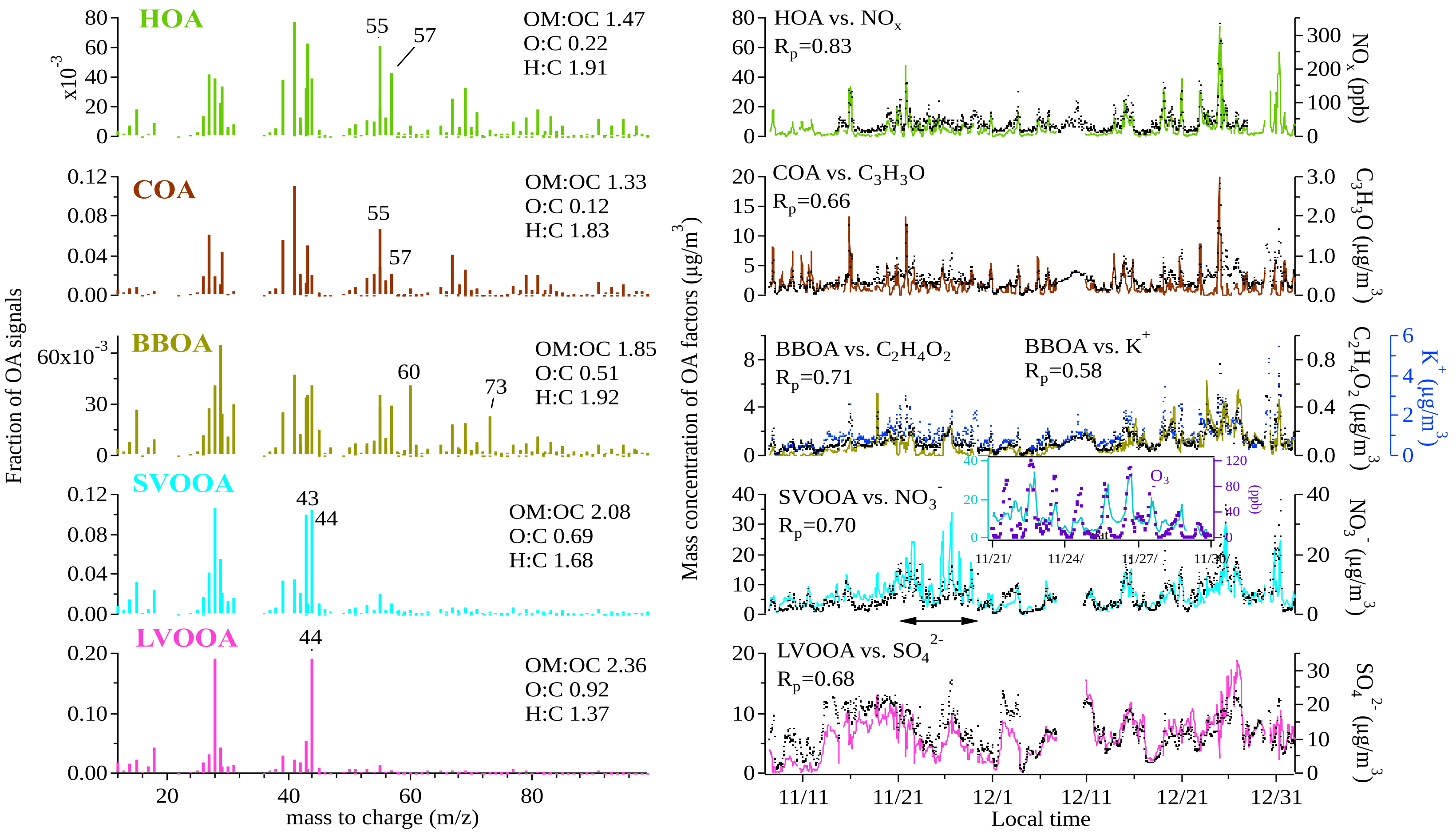
Time series of Overall organics mass spectra → Separate into a number of factors



Each factor corresponds to a large group of OA constituents with similar chemical composition and temporal behavior.

$$\mathbf{ORG} = \mathbf{TS} \times \mathbf{MS} + \mathbf{E}$$

Organic factor analysis



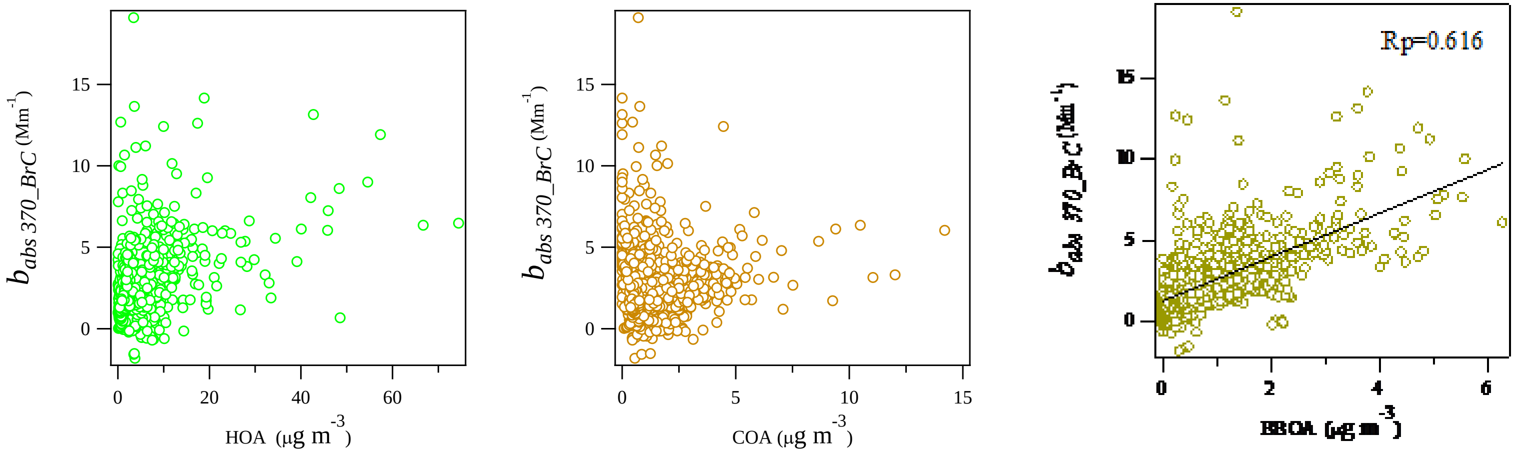
POA:

- Hydrocarbon-like organic aerosol (HOA);
- Cooking organic aerosol (COA);
- Biomass burning related organic aerosol (BBOA)

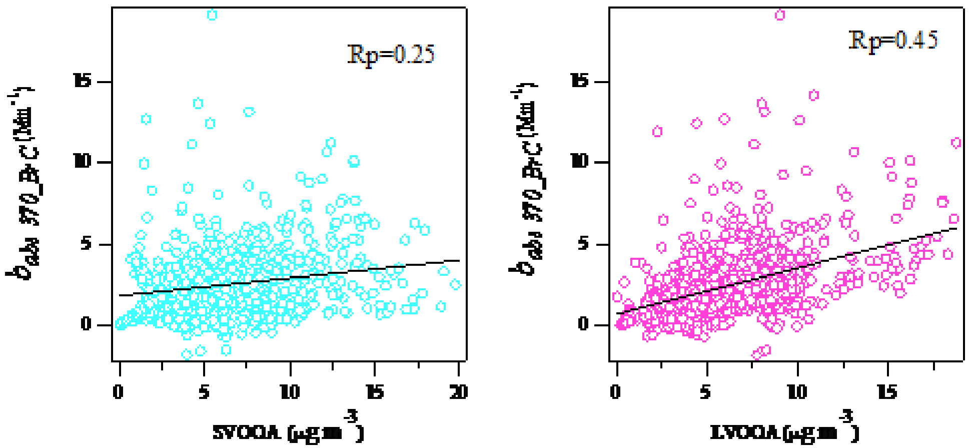
SOA:

- Semi-volatile oxygenated organic aerosol (SV-OOA);
- Low-volatility oxygenated organic aerosol (LVOOA)

Correlation of light absorption by BrC with OA

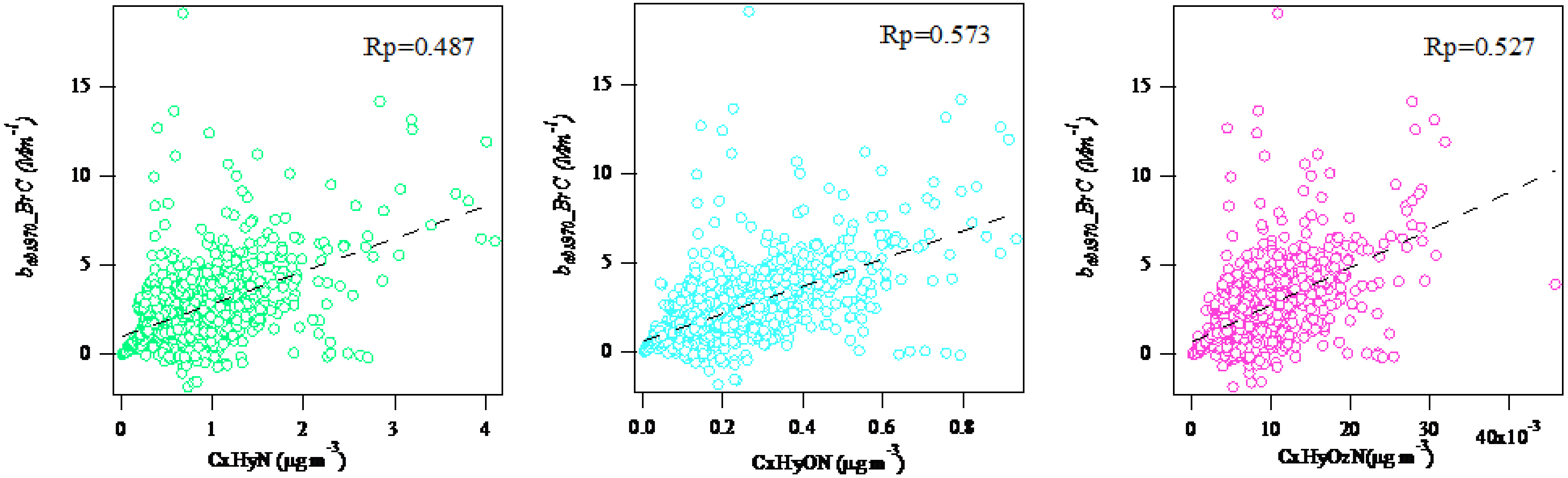


BrC was associated with BBOA, biomass burning related aerosol.



BrC was also associated with LVOOA. Possible source: SOA from VOCs

Correlation of light absorption by BrC with C_xH_yN,C_xH_yON and $C_xH_yO_xN$



C_xH_yN, C_xH_yON and $C_xH_yO_xN$ may be responsible for the observed optical properties of BrC.

Conclusions

I. **Light absorption contribution due to BrC** at Guangzhou, Panyu was obtained, with 21.1% of the total aerosol absorption at 370nm, 15.2% at 470nm, 9.6% at 520 nm, 7.4% at 590nm and 7.2% at 660 nm.

II. The BrC were **associated with BBOA and LVOOA** at this site. Possible source: Biomass burning and SOA from VOCs.

III. **CxHyN, CxHyON and CxHyOxN** may be responsible for the observed optical properties of BrC.

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