Yale-NUIST Center on Atmospheric Environment

Biomass Burning Contribution to Carbonaceous Component and Light-absorbing Property of Aerosols in Nanjing Urban Area during a Wintertime Pollution Episode

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Liu Xiaoyan

Outline

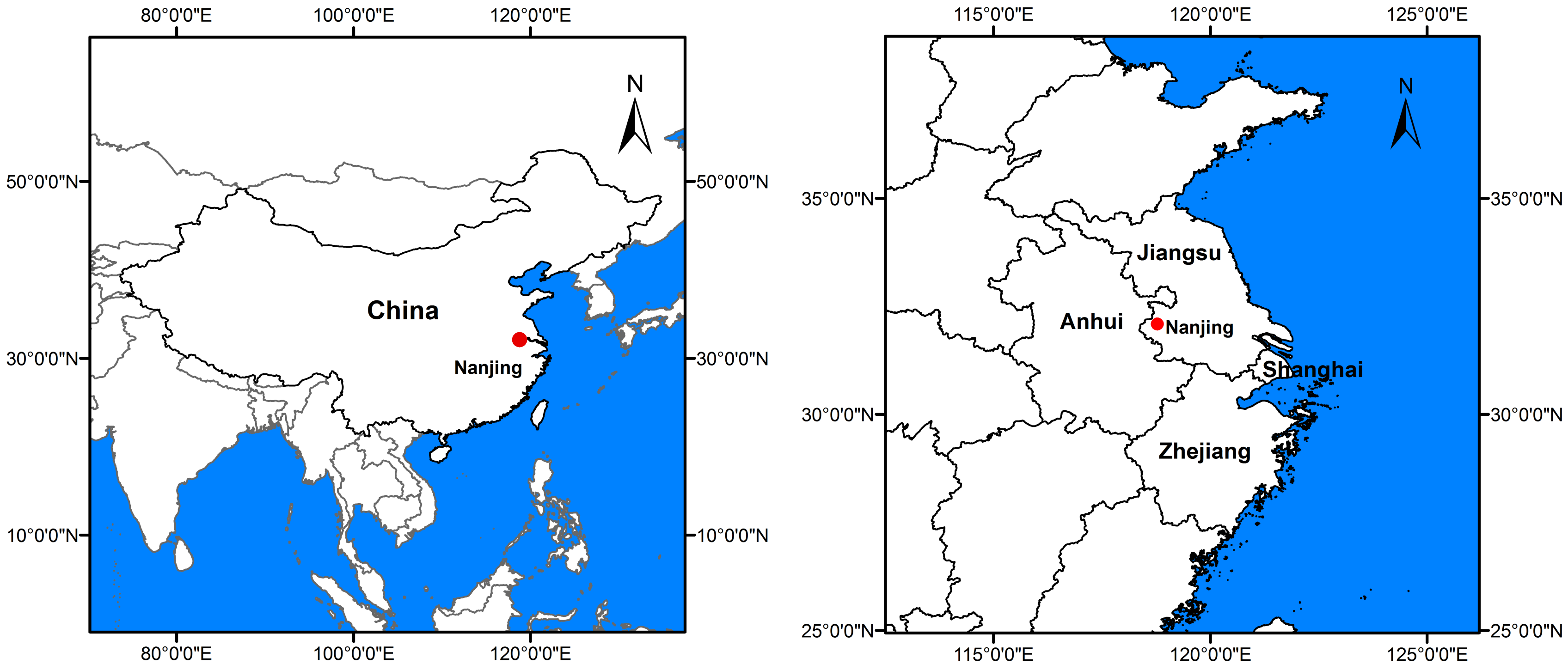
- Background
- Materials and method
- Results and discussion
- Conclusion

Background

- Biomass burning is one of the important sources of aerosol pollution, drawing a lot of attention *(J. S. Reid., 2005; Elisa et al., 2014)*.
- Under the strict control of straw burning activities, local air quality can still be impacted by biomass combustion *(T. Novakov., 2000)* .
- Biomass burning contributes Brown Carbon (BrC) to ambient air, which can enhance light-absorbing ability of aerosol *(Cheng et al., 2016; Du et al., 2014)*.
- If BrC is a product of biomass burning, can it be a tracer of biomass combustion?

Material and method

➢Sampling Site



➢ $PM_{2.5}$ sampling instrument

- Sampler: KC 1000
- Sample collector: quartz filter （8×10 inch）

➢ Sampling frequency and time :

Time	Frequency	Notes
14th Jan 16:30-26th Jan 18:00 in 2015	Every 3 hrs	Afternoon of 14th : after light rain Morning of 25th : light rain 9 a.m. to 1 p.m. of 25th :power failure
26th Jan 18:00-29th Jan 00:00 in 2015	Every 6 hrs	27th to 29th : rain and snow

Material and method

➢ Laborotary analysis of chemical species

Chemical species	Instrument
Carbonaceous component: OC EC	Sunset EC/OC analyzer
Water-soluble organic carbon: WSOC	TOC-L analyzer
Water-soluble ion	ICS 5000+ (anion/cation collumn and CD)
Saccharide	ICS 5000+ (MA collumn and ED)
Brown Carbon*	Ultraviolet spectrophotometer

Brown carbon is represented by the light-absorbing property of WSOC.*

Materials and method

- Gaseous pollutants -- CO SO_2 NO_2

  Shanxi Road Station

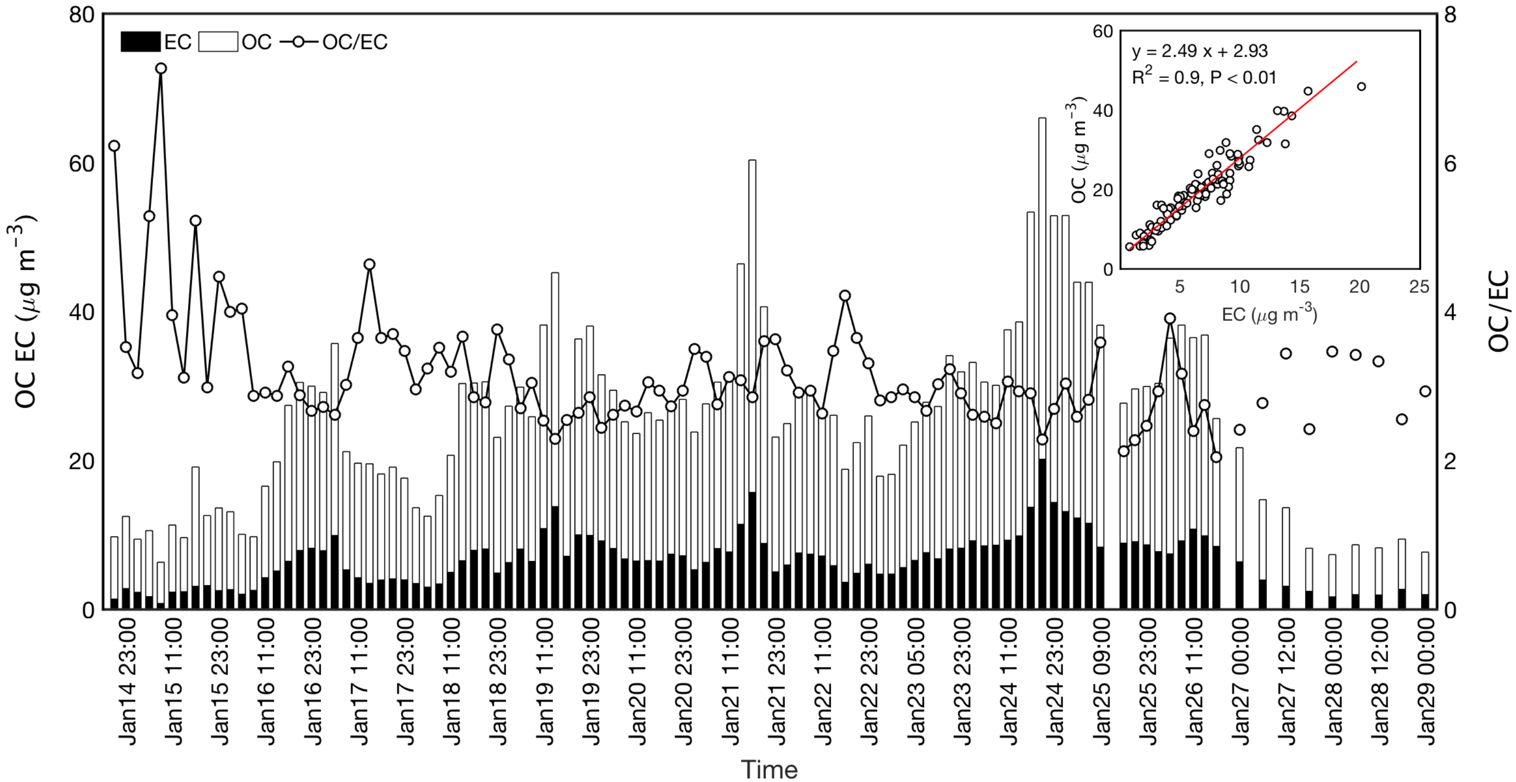
- TrajStat (V 1.2.6)

  Air mass trajectory statistics software

- Active Fire Data (NASA)

  https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data

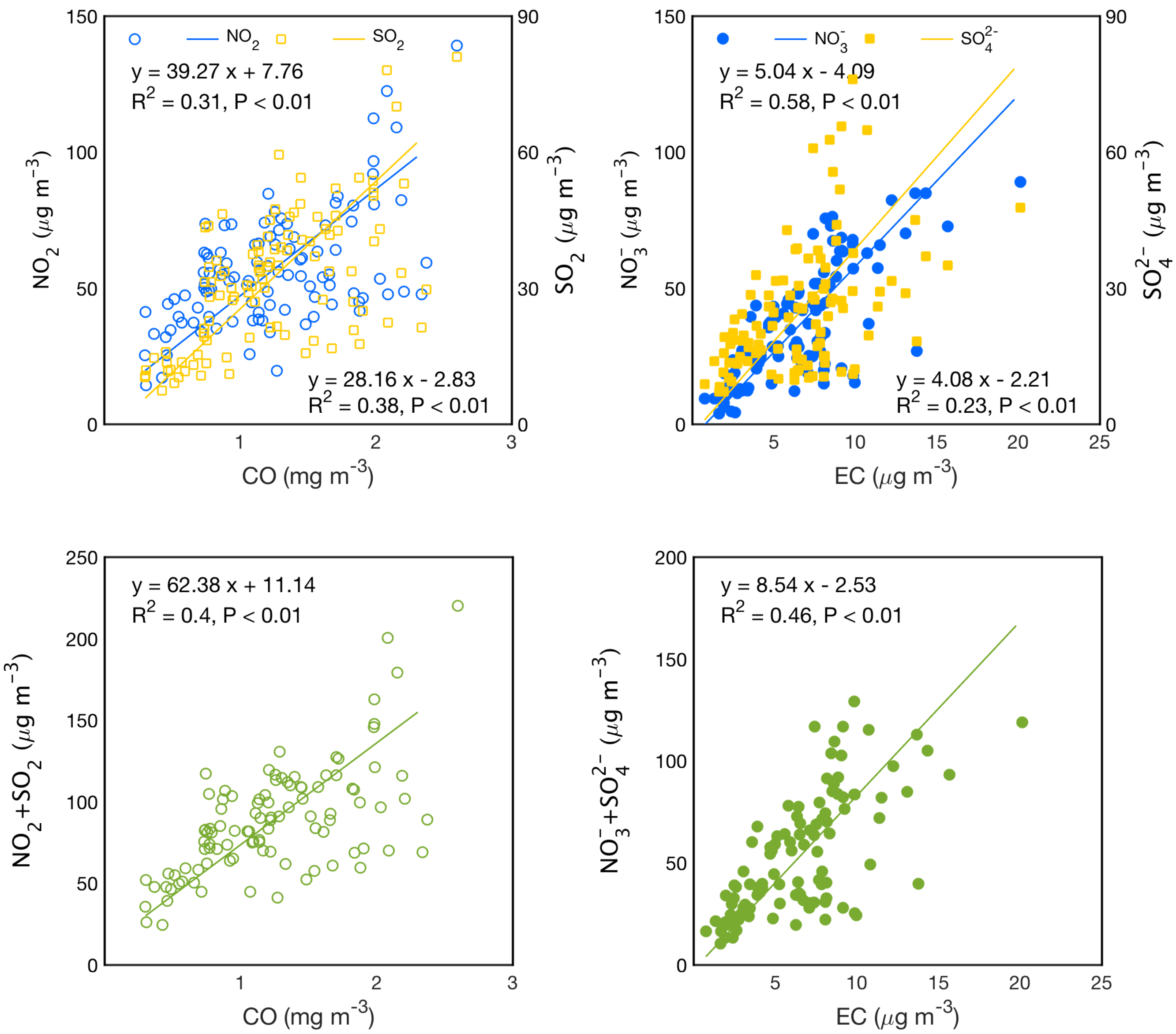
Results and discussion

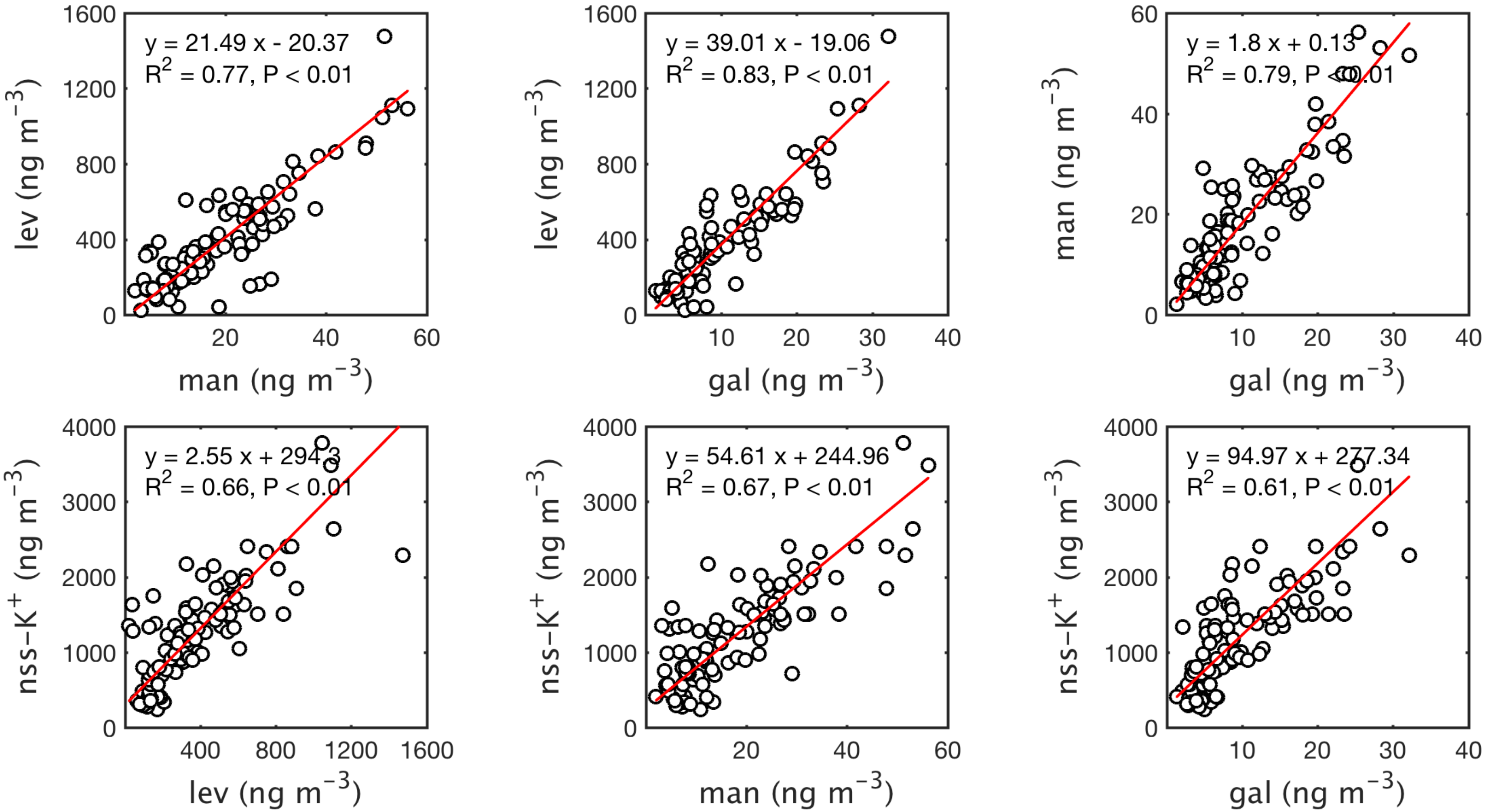


		Mean	STD	Min	Max	Max/Min
OC	μg m^{-3}	19.45	8.62	5.54	45.83	8.27
EC		6.62	3.46	0.76	20.13	26.48
OC/EC		3.15	0.77	2.04	7.26	3.55

In the winter of 2015, the seasonal mean OC and EC level in $PM_{2.5}$ were 22.54 ± 9.63 and 8.24±3.13 μg m^{-3}, respectively.
(B. Li et al., 2015)

Relationship between combustion and fossil-fuel combustion





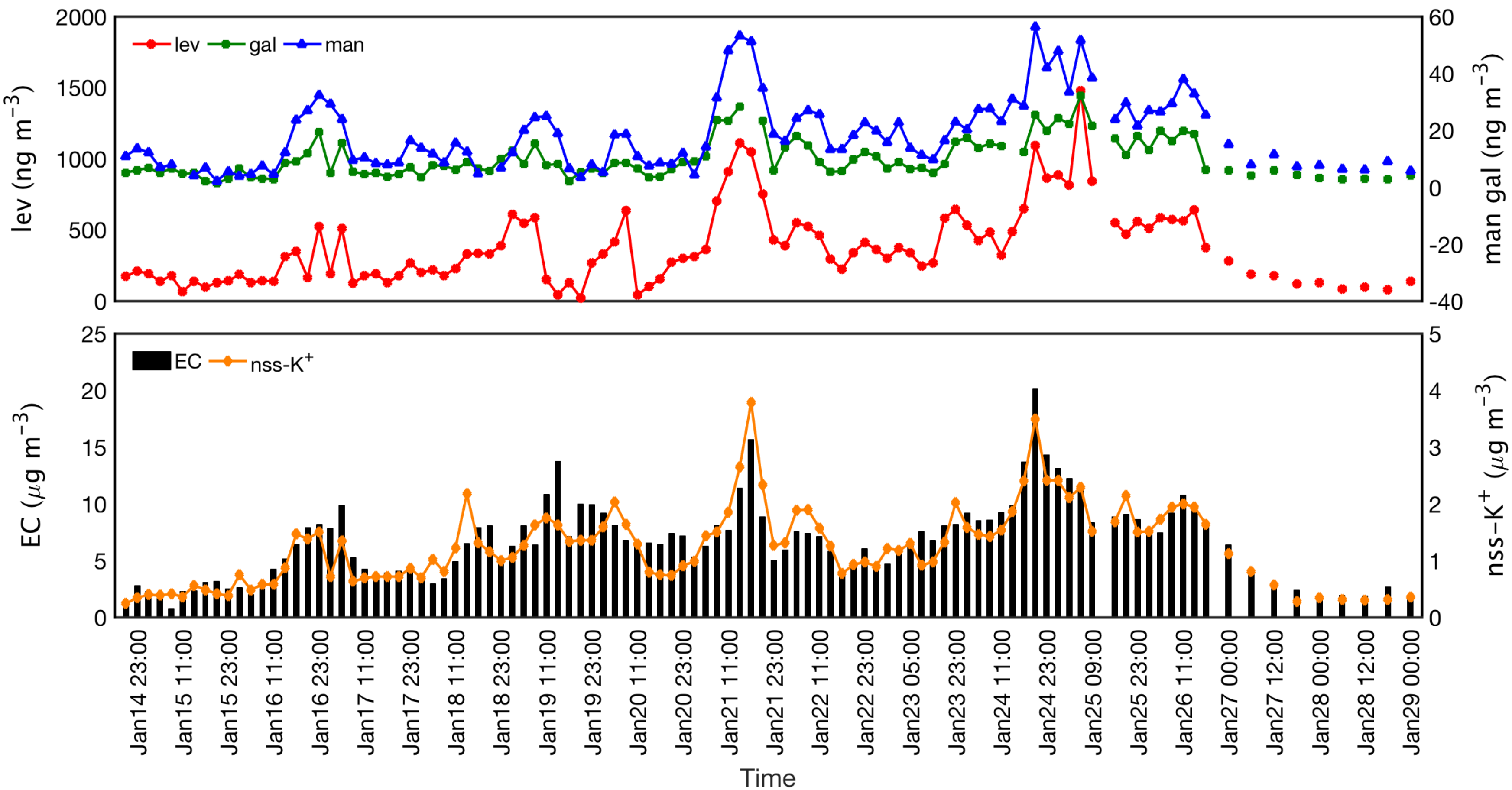
Note: lev, man, gal and nss-K⁺ respectively refer to concentration of levoglucosan, mannosan, glactosan and non-sea-salt potassium.

$$nss\text{-}K^+ = K^+ - 0.0335 \times Na^+$$

(*F. Cao et al., 2015; Lai et al., 2007*)

Comparison of levoglucosan concentration range in $PM_{2.5}$ during this study with those reported in the literature.

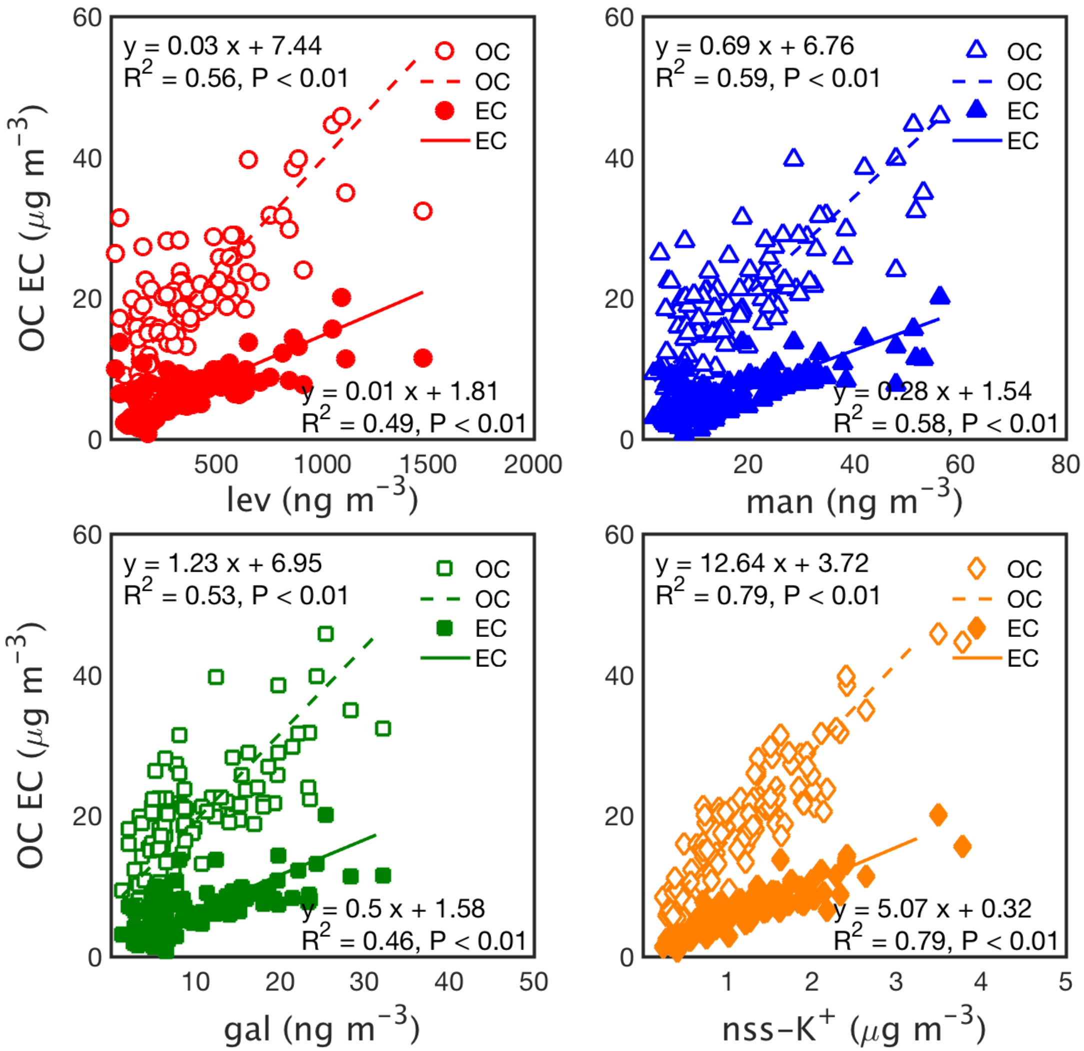
Sampling Site	Site Type	Sampling Time	Concentration Range ng m^{-3}	Reference
Azores,Portugal	coastal	Winter	6.6	(Puxbaum et al., 2007)
Puy de Dôme,France	coastal	Winter	18.3	
Schauinsland,Germany	coastal	Winter	33.7	
Sonnblick, Austria	coastal	Winter	12.4	
Jilin, China	forest	July	42 (32-67)	(Wang et al., 2008)
Shanghai, China	forest	June,	143 (20-212)	
Guangdong, China	forest	August	25 (0.3-61)	
Hainan, China	forest	November	107 (19-398)	
Beijing, China	urban	Summer	230	(Cheng et al., 2013)
		BB episode	750	
		Typical summer	120	
		Winter	590	
		Firework episode	460	
		Typical winter	640	
Shanghai, China	urban	Spring	66 (18-159)	(X. Li et al., 2016)
		Summer	28 (8.6-194)	
		Autumn	229 (13-1606)	
		Winter	161 (26-614)	
Nanjing,China	urban	Winter	373.12 (22.4-1475.45)	Current study



		Mean	STD	Min	Max
levoglucosan		373.12	267.92	22.40	1475.45
mannosan	ng m^{-3}	18.47	12.51	2.09	56.20
galactosan		9.86	6.71	1.35	32.17
nss-K$^+$	μg m^{-3}	1.24	0.68	0.24	3.78

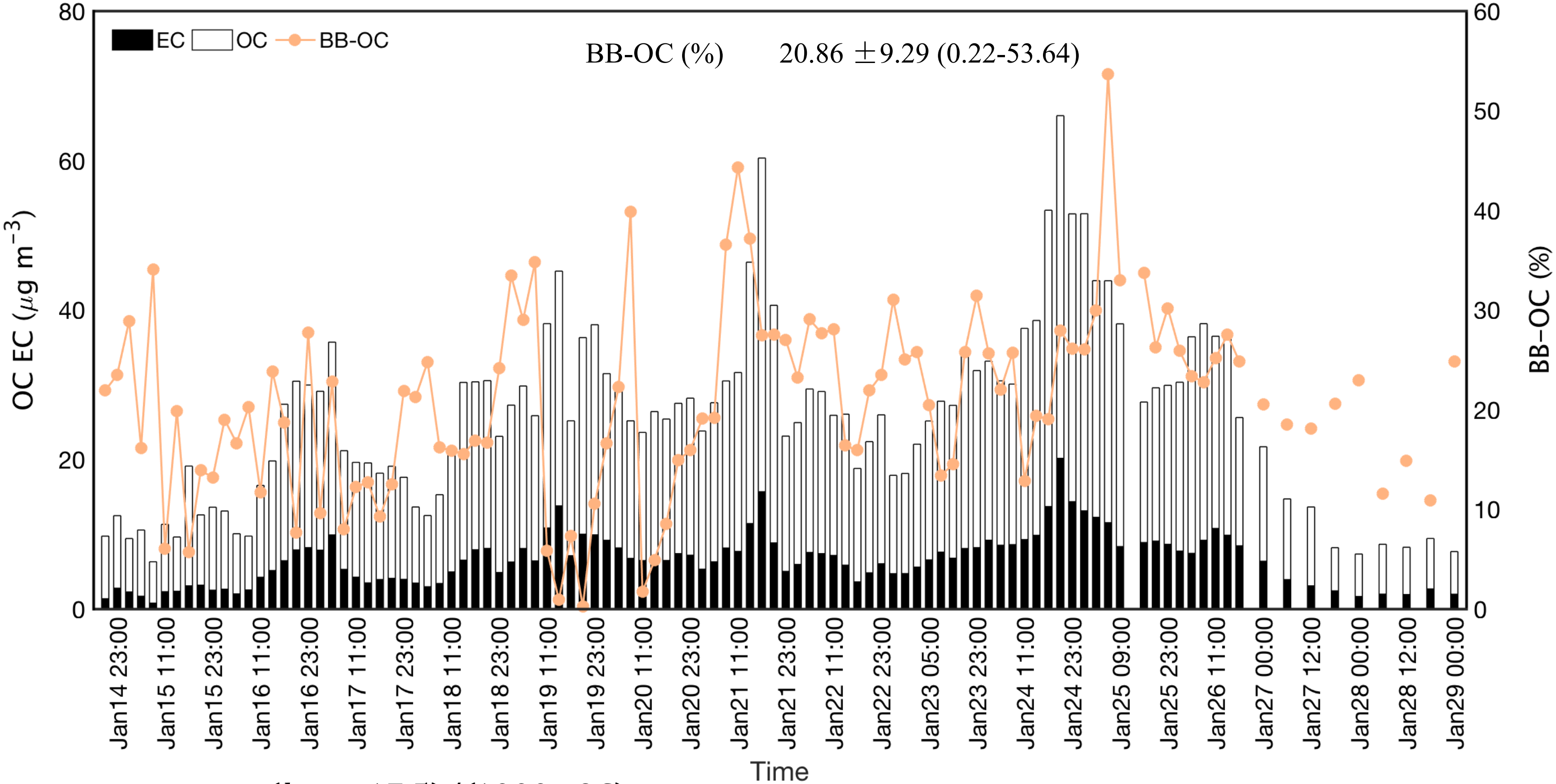
The consistent trend between EC and BB-marker suggests the major share of biomass burning among all kinds of combustion activities in this campaign.

Correlations of OC and EC vs BB markers



- $R^2_{OC} > R^2_{EC}$
- $0.5 < R^2_{OC} < 0.80$
- $R^2_{nss\text{-}K+} > R^2_{saccharides}$

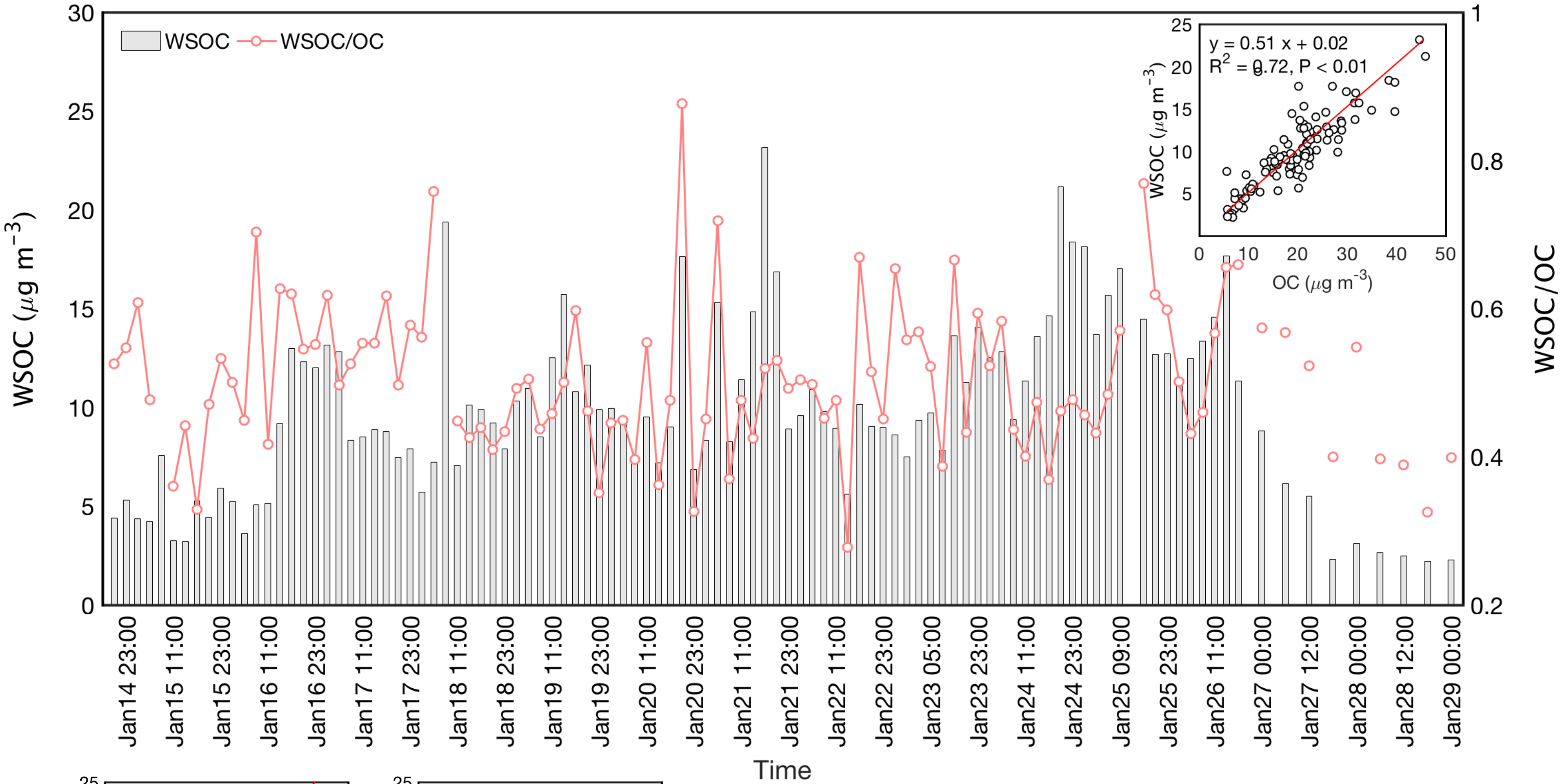
Quantification of BB contribution to OC

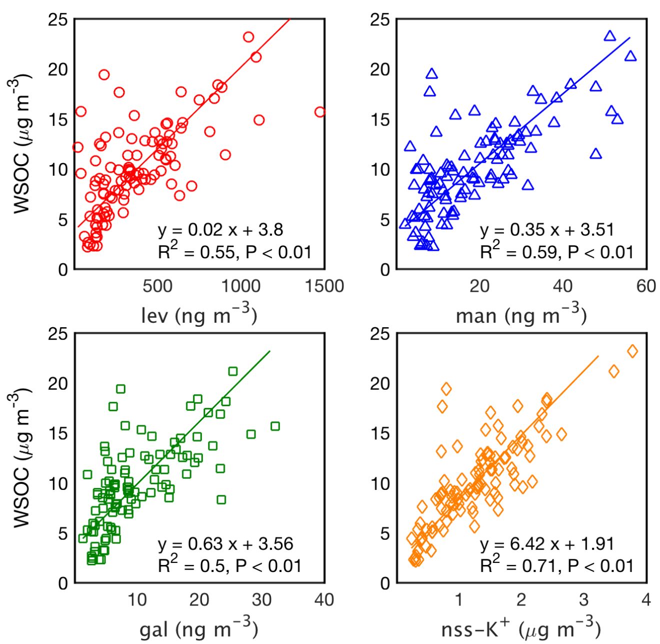


$$\mathrm{BB-OC} = \frac{(lev - 17.5)/(1000 \times OC)}{0.082} \times 100\%,$$

lev and OC respectively in terms of $ng\ m^{-3}$ and $\mu g\ m^{-3}$

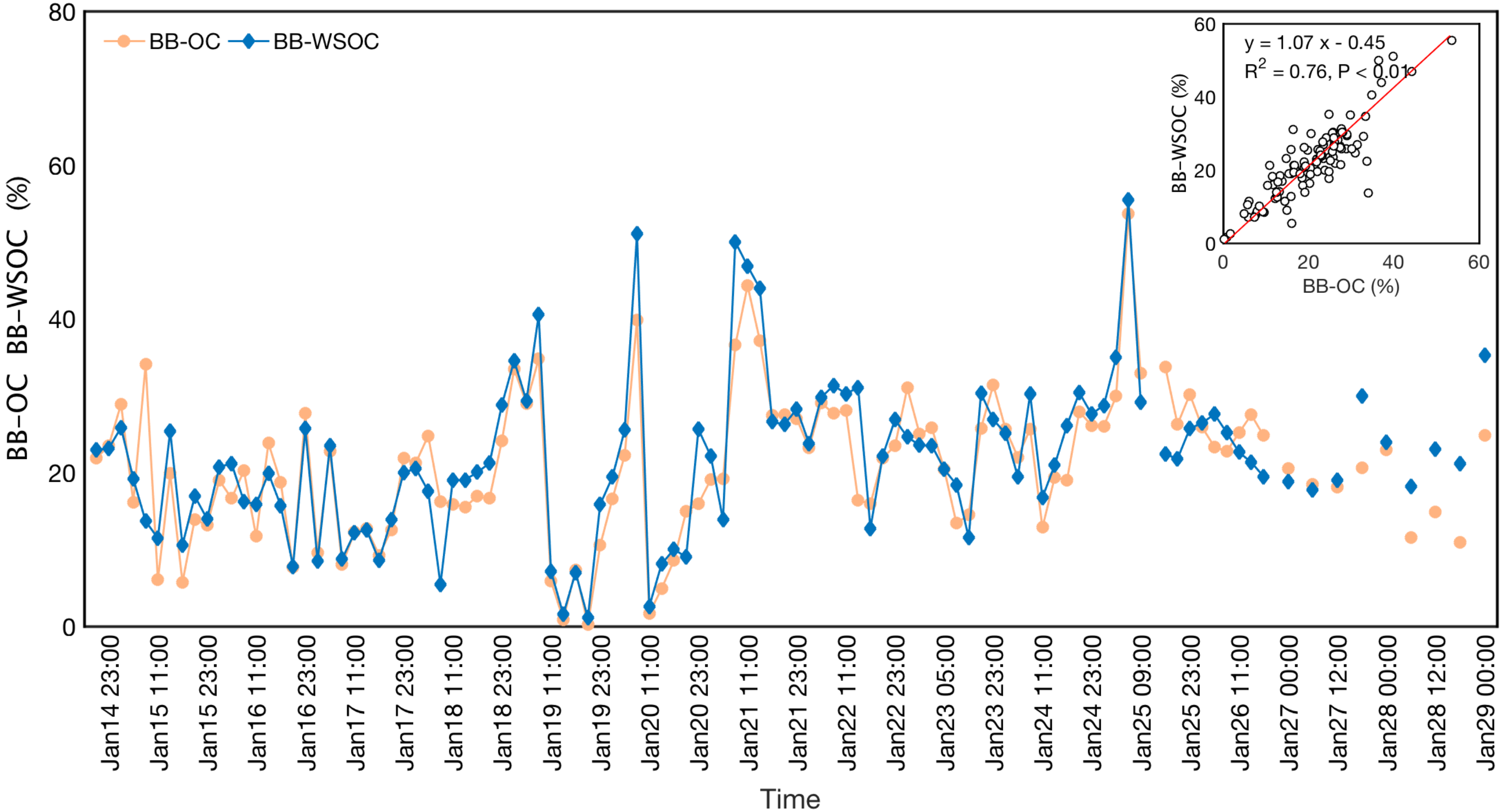
Lev/OC has been used to determine BB-OC in many studies *(Zdrahal et al., 2002; Puxbaum et al., 2007; Zhang et al., 2010)*. In biomass burning source emission tests for three major types of cereal straw (corn, wheat and rice) in China, *Zhang et al. (2007)* reported a levoglucosan to OC ratio of 0.082 for $PM_{2.5}$. BB-OC varied in a range of 18–38% in Beijing rural areas *(Zhang et al., 2008).*





	Mean	STD	Min	Max
WSOC (μg m^{-3})	9.90	4.38	2.20	23.16
WSOC/OC	0.51	0.10	0.28	0.88

WSOC usually accounted for ~50% of OC in ambient $PM_{2.5}$ *(Bikkina Srinivas and M.M. Sarin, 2014; Tang et al., 2016; Z. Du et al., 2014)*

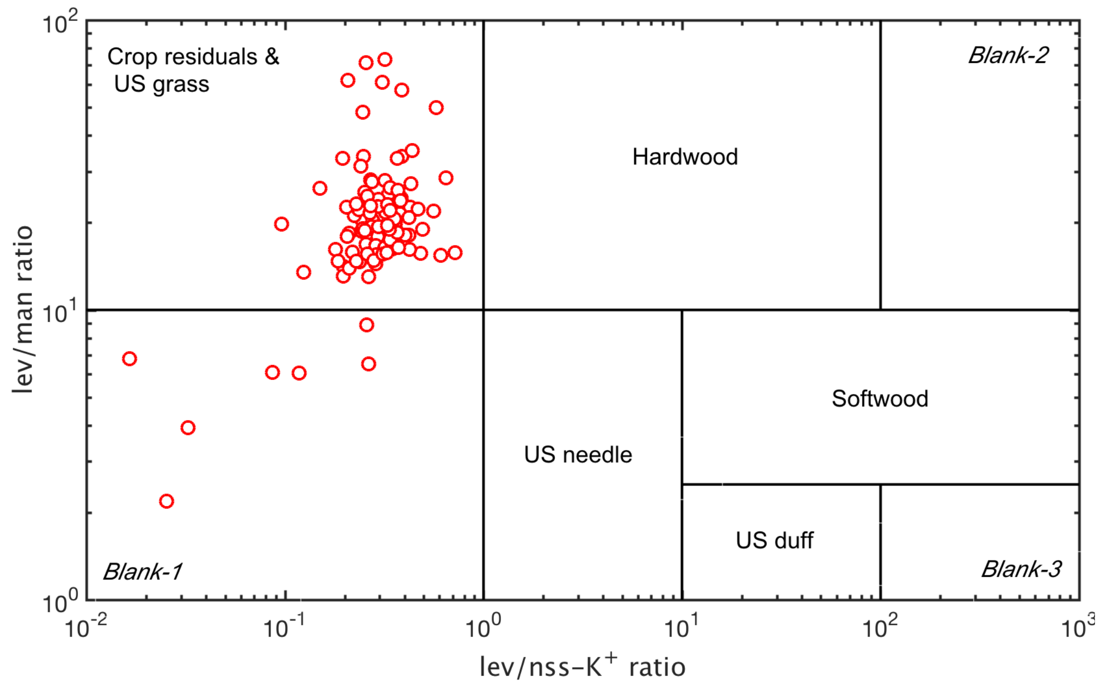


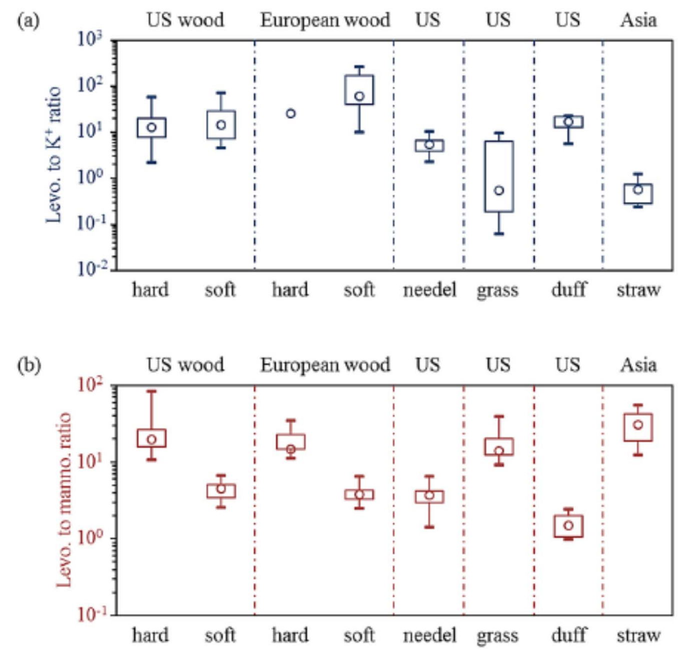
$$BB-WSOC = \frac{(lev/WSOC)_{ambient}}{(lev/WSOC)_{source}} \times 100\%,$$

$lev/WSOC\ in\ term\ of\ \mu g\ \mu gC^{-1}$

	Contribution Range (%)
BB-OC	20.86 ±9.29 (0.22-53.64)
BB-WSOC	21.95 ±9.97(1.09-55.41)

The $(lev/WSOC)_{source}$ ratio of 0.17 μg μgC^{-1} from the test burns of rice straws and wheat straw *Yan et al. (2015).* Results showed that WSOC from biomass burning contribution accounted for 23±7% in wintertime.





(Y. Cheng et al., 2013)

	Ambient samples			
	BB episode	Typical summer	Firework episode	Typical winter
levo./K^+	0.11 ± 0.06	0.21 ± 0.16	0.16 ± 0.09	0.51 ± 0.15
levo./manno.	25.01 ± 13.20	12.65 ± 3.38	10.88 ± 1.23	9.01 ± 1.47
	Source samples			
	Wheat straw	Corn straw	Pine wood	Poplar wood
levo./K^+	0.10 ± 0.00	0.21 ± 0.08	23.96 ± 1.82	5.89 ± 0.53
levo./manno.	12.71 ± 1.53	19.48 ± 3.37	2.69 ± 0.03	5.98 ± 1.40

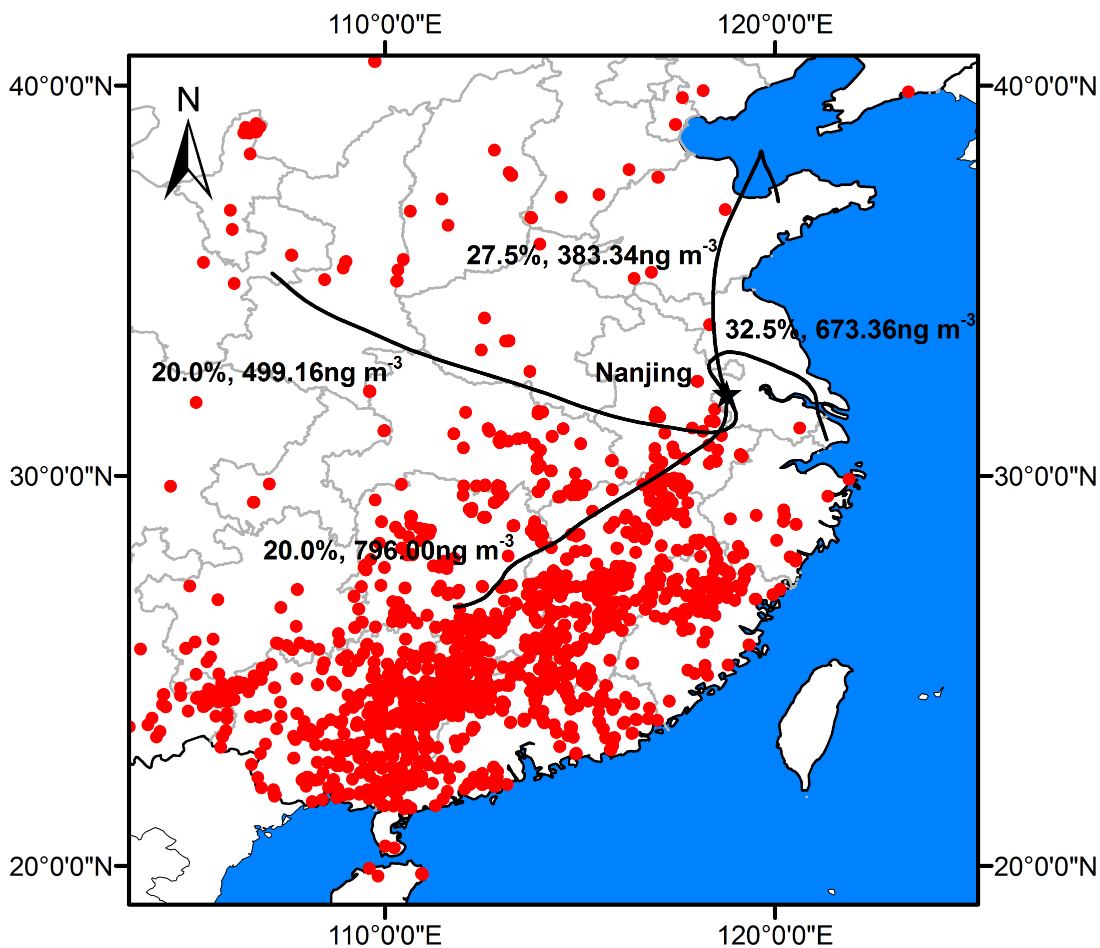
(Y. Cheng et al., 2013)

	Mean	range
lev/man	22.54 ± 12.29	2.19 - 73.23
lev/nss-K^+	0.30 ± 0.12	0.02 – 0.72
nss-K^+/OC	0.06 ± 0.02	0.03 – 0.11

(This study)

Source -- long range transport

- Hysplit + Fire spot



Computing the light-absorbing property parameters

Absorption coefficient

$$b_{\text{abs}} = (A_{\lambda} - A_{700}) \times (V_{water} \times Factor) \times \ln(10) \div (A_{aero} \times L)$$

- b_{abs} (M m^{-1}) is the absorption coefficient;
- A_{λ} and A_{700} refer to measured absorbance at any wavelength and 700 nm, respectively. A_{365} is used to represent absorption coefficient of this sample；
- V_{water} (mL)corresponds to the volume of the aqueous extract which is water ；
- Factor is used to estimate the absorption signal for the full filter；
- V_{aero} (m^3) refers to volume of air filtered；
- L (mm) is the path length of the cell (10mm).

Absorption Angstrom exponents (AAE)

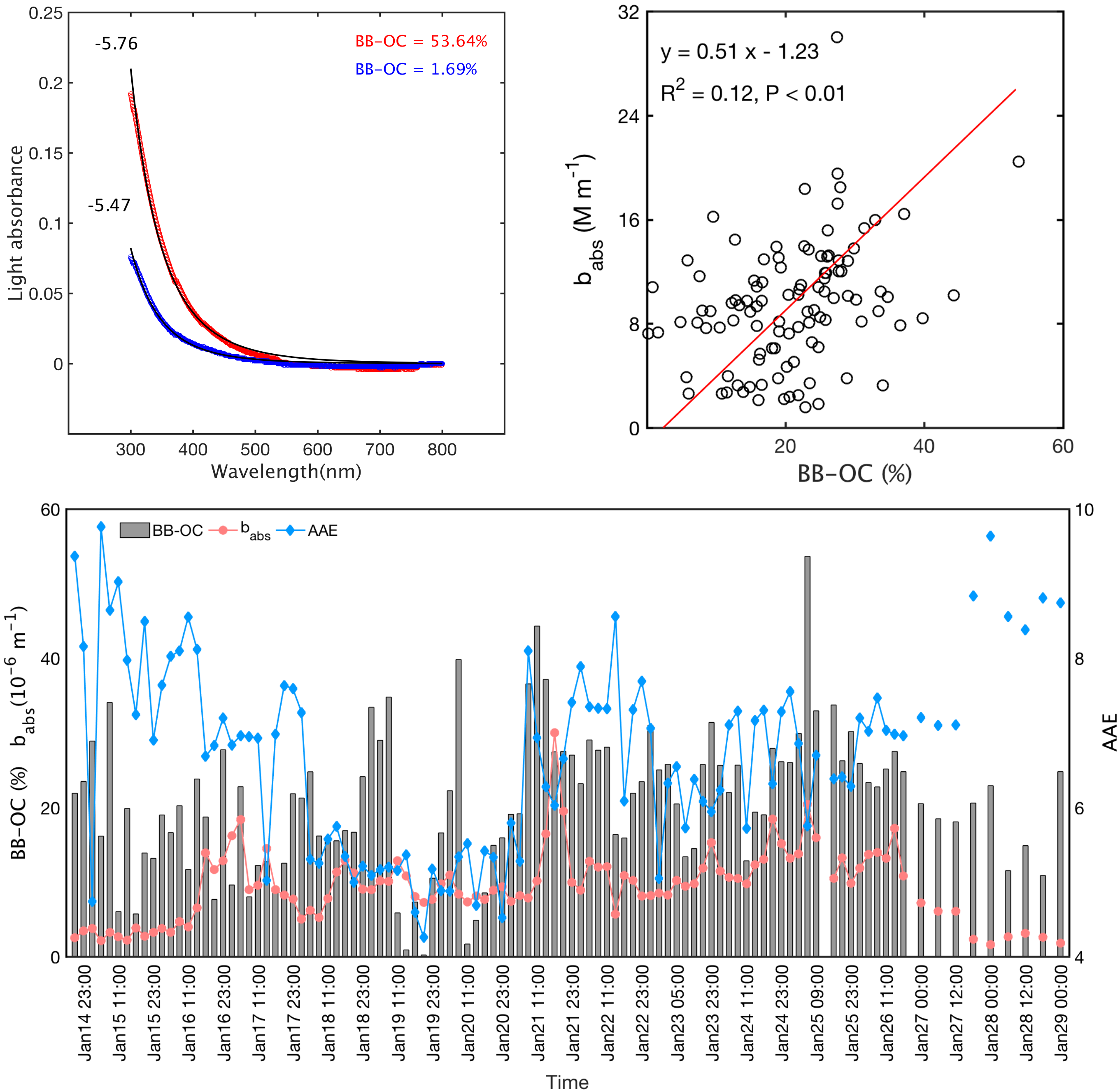
$$b_{\lambda} \approx K \cdot \lambda^{-AAE}$$

- b_{abs} (m^{-1}) is the absorption coefficient
- λ（310-470nm)

Mass Absorption Efficiency of BrC

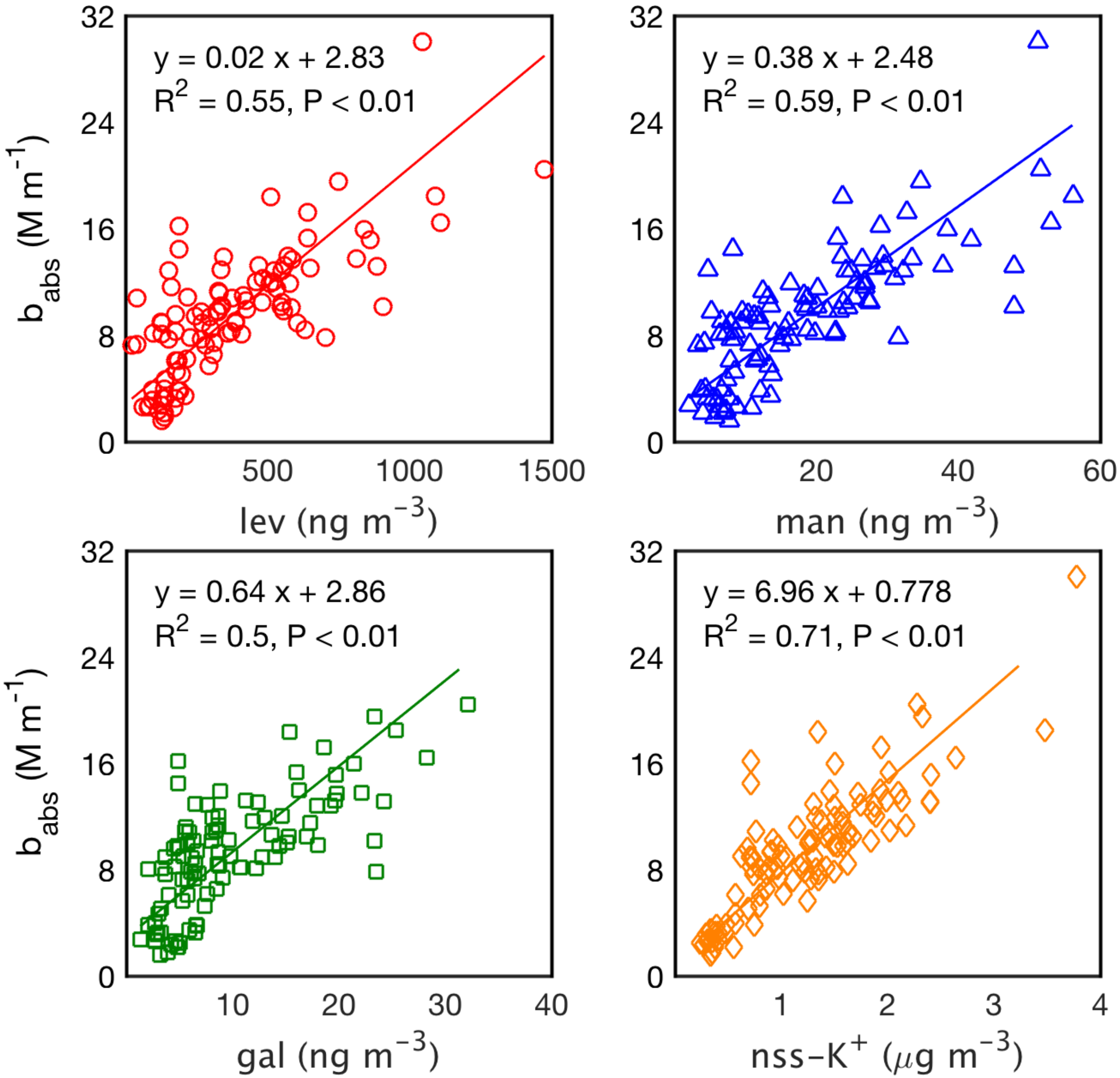
$$\text{MAE of BrC} = \sigma_{abs-BrC} = b_{abs}/WSOC$$

- $\sigma_{abs-BrC}$ (m^2 g^{-1}) is mass absorption efficiency of light absorbing water-soluble organics (BrC);
- b_{abs} (m^{-1}) refers to absorption coefficient;
- WSOC (μg m^{-3}) means the concentration of water-soluble organic carbon.

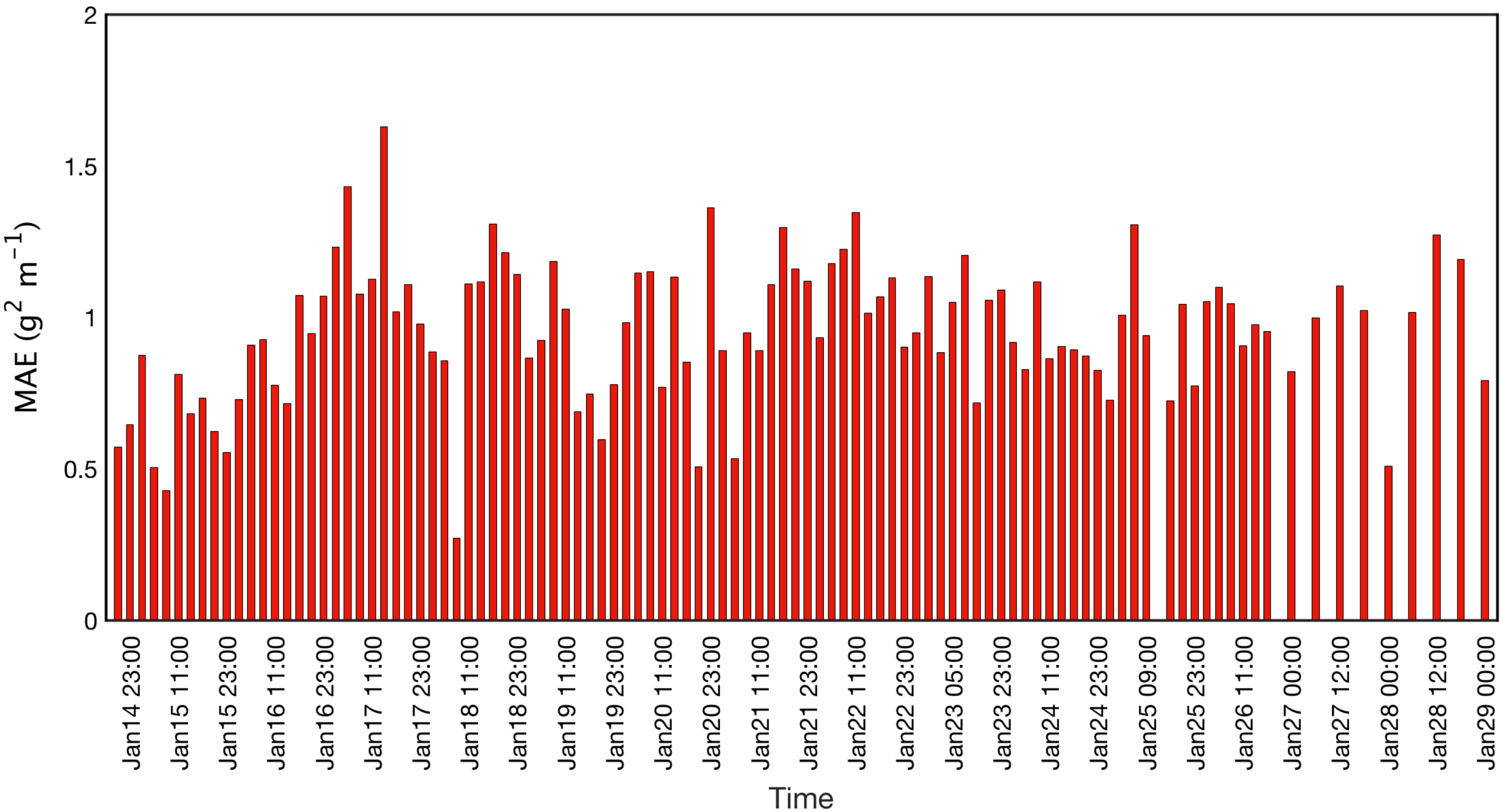


-5.76
-5.47
BB-OC = 53.64%
BB-OC = 1.69%
Light absorbance
Wavelength(nm)
y = 0.51 x - 1.23
R2 = 0.12, P < 0.01
babs (M m-1)
BB-OC (%)
BB-OC
babs
AAE
BB-OC (%) babs(10-6 m-1)
Time

Correlations of biomass burning intensity vs light-absorbing property



MAE of WSOC



		Mean	STD	Min	Max
babs	M m^{-1}	9.44	4.75	1.58	30.01
AAE		6.51	0.10	6.33	6.78
MAE	g^2 m^{-1}	0.95	0.23	0.27	1.63

MAE of BrC is reported 0.78±0.24 and 0.7±0.2m^2 g^{-1} ,respectively, in the Indo-Gangetic Plain during January and Beijing during wintertime BB episode *(Bikkina Srinivas et al., 2014; Cheng et al.,2011).*

Conclusion

- The major source of pollution was fuel combustion. Biomass burning contribution to OC and WSOC was 20.86 ± 9.29 (0.22-53.64) % and 21.95 ±9.97(1.09-55.41), respectively.
- Biomass burning could release mass Brown Carbon to the atmosphere, but the origin of Brown Carbon was non-unique, thus cannot be treated as the marker of biomass burning.
- The light-absorbing ability of ambient aerosol was very strong during study period. The mass absorbing efficiency (MAE) of WSOC was 0.95 ± 0.23 (0.27-1.63) g^2 m^{-1}.


Q & A