Yale 耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

Optical properties of light absorbing organic aerosols(brown carbon) in North Nanjing

Reporter: Bao Mengying

2017.12.08

Outline

Current work

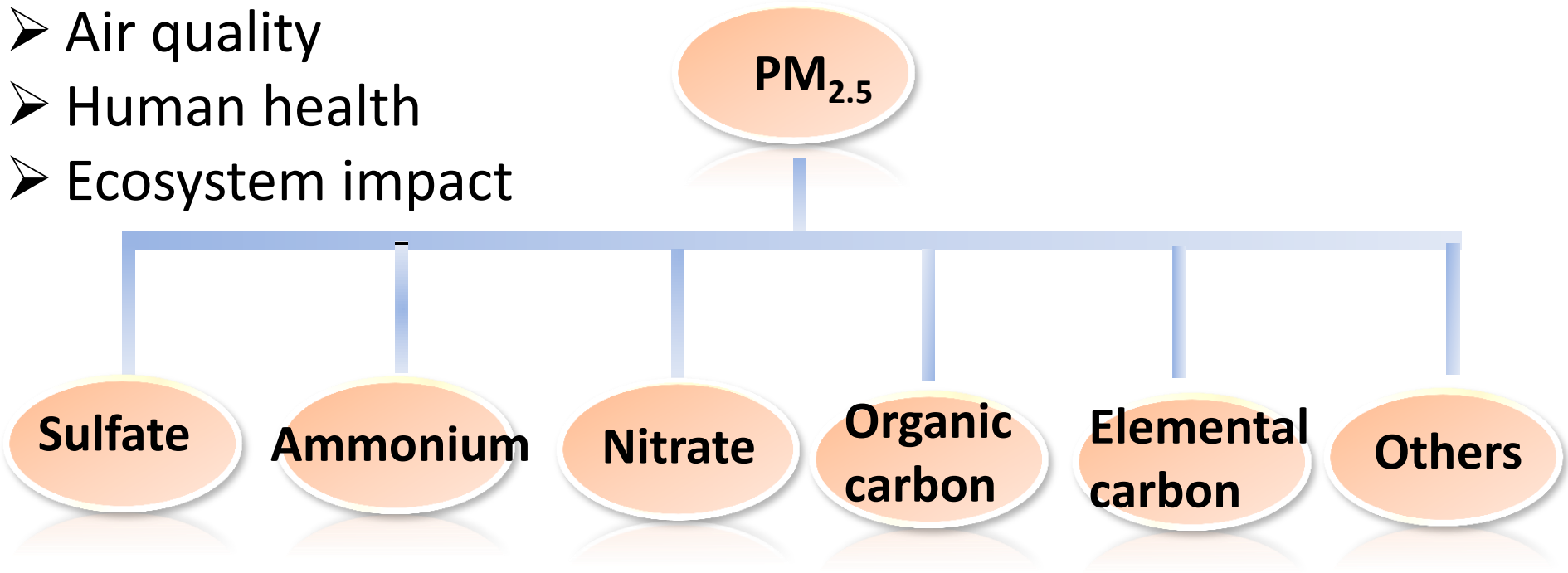
1. Background
2. Experiment
3. Results and discussion
4. Conclusion

Outlook

Background

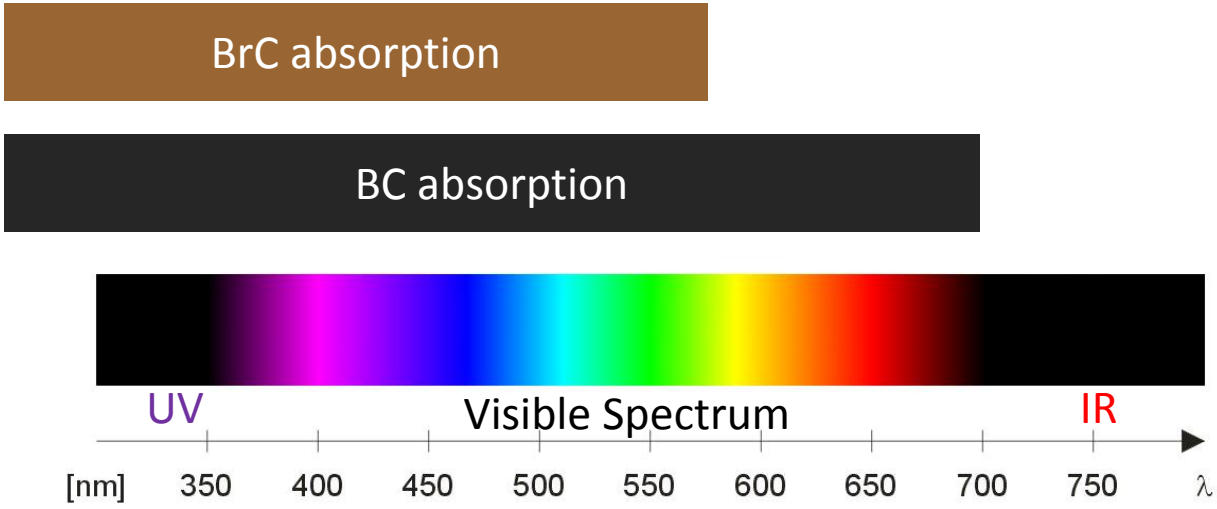
Role of $PM_{2.5}$:

- Climate forcing
- Air quality
- Human health
- Ecosystem impact



Brown Carbon: The Absorbing Organics

- Recent studies show some organic aerosols can absorb light (so-called ”brown carbon”: BrC) *(*Andreae and Gelencsér, 2006 ; *Arola et al., 2011; Hecobian et al., 2010; Chakrabarty et al., 2010 etc.)*
- Usually found in biomass burning and biofuel emissions.
- Most absorbing at UV wavelengths, leading to a high absorption angstrom exponent (AAE).
- BrC contributes to global warming but its effect has not been well estimated.

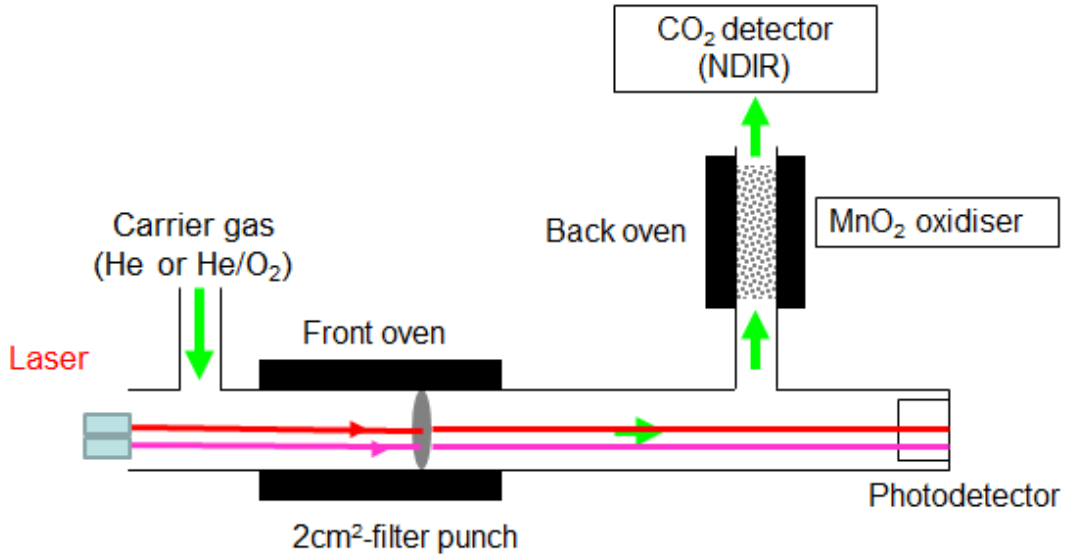


Experiment

- Online Data: OC, EC , BrC
- Observation time: 2015.6-2016.8
- Observation site: Nanjing University of Information Science and Technology (NUIST)

Brown Carbon（BrC）

$dEC=EC_{405nm} - EC_{658nm}$



Drawn by Prof. Zhang Yanlin

Mass Absorption Efficiency(MAE)

$$ATN = \ln(\frac{I_0}{I}) \bullet 100$$ ***Eq.* (1)**

ATN is the light attenuation.

where I is the intensity of transmitted light before the analysis, and I_0 is the intensity of incident light that is the measured signal after the analysis.

$$b_{ATN} = ATN \times \frac{A}{V}$$ ***Eq.* (2)**

b_{ATN} is the attenuation coefficient(M m^{-1}=$10^{-6}m^{-1}$).

where A and V are the filter area (cm^2) and sampled air volume (m^3).

$$b_{abs} = \frac{b_{ATN}}{C \bullet R(ATN)}$$ ***Eq.* (3)**

b_{abs}(M m^{-1}) is the absorption coefficient.

$$R(ATN) = (\frac{1}{f} - 1)(\frac{\ln(ATN) - \ln(10)}{\ln(50) - \ln(10)}) + 1 = (\frac{1}{f} - 1)\frac{\ln(0.1ATN)}{1.609} + 1$$ ***Eq.* (4)**

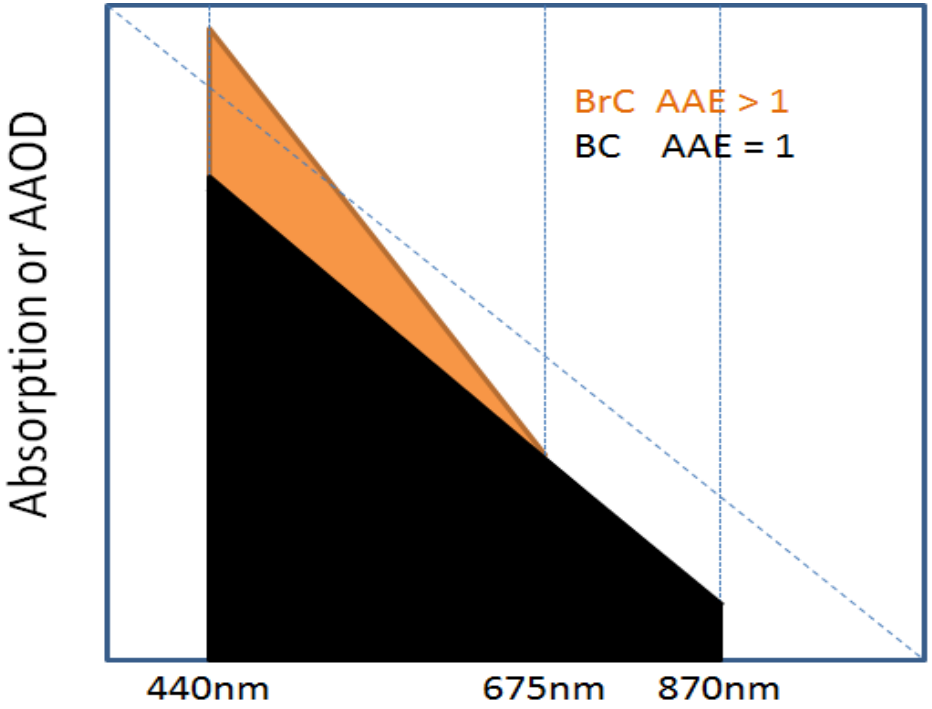
$$MAE = \frac{b_{abs}}{EC} = \frac{ATN}{EC_S \times C \times R(ATN)}$$ ***Eq.* (5)**

Where C and R(ATN) are two empirical factors that are often used to correct the artifacts in filter based measurement due to the multiple scattering and shadowing effects. ECs (μg C cm^{-2}) is the filter loading of EC. C value of 2.14 and f value of 1.1 were adopted in this study.

(Sarin and Srinivas, 2013; Ram and Sarin, 2009; Shen et al., 2013; Cheng et al., 2011)

Deriving BrC Absorption from Measurements

- AAE exhibits the spectral dependence of aerosol absorption, which is related to size, chemical components of aerosol particle and incident radiation wavelength (Chakrabarty et al., 2010; Gyawali et al., 2009; Flowers et al., 2010).



（Source: Wang and Heald, 2015）

$$AAE = -\frac{\ln(Babs(\lambda 1)) - \ln(Babs(\lambda 2))}{\ln(\lambda 1) - \ln(\lambda 2)}$$

Babs(M m^{-1}) is the absorption coefficient. In this study, λ1 and λ2 are 405 and 658 nm respectively.

Data quality control

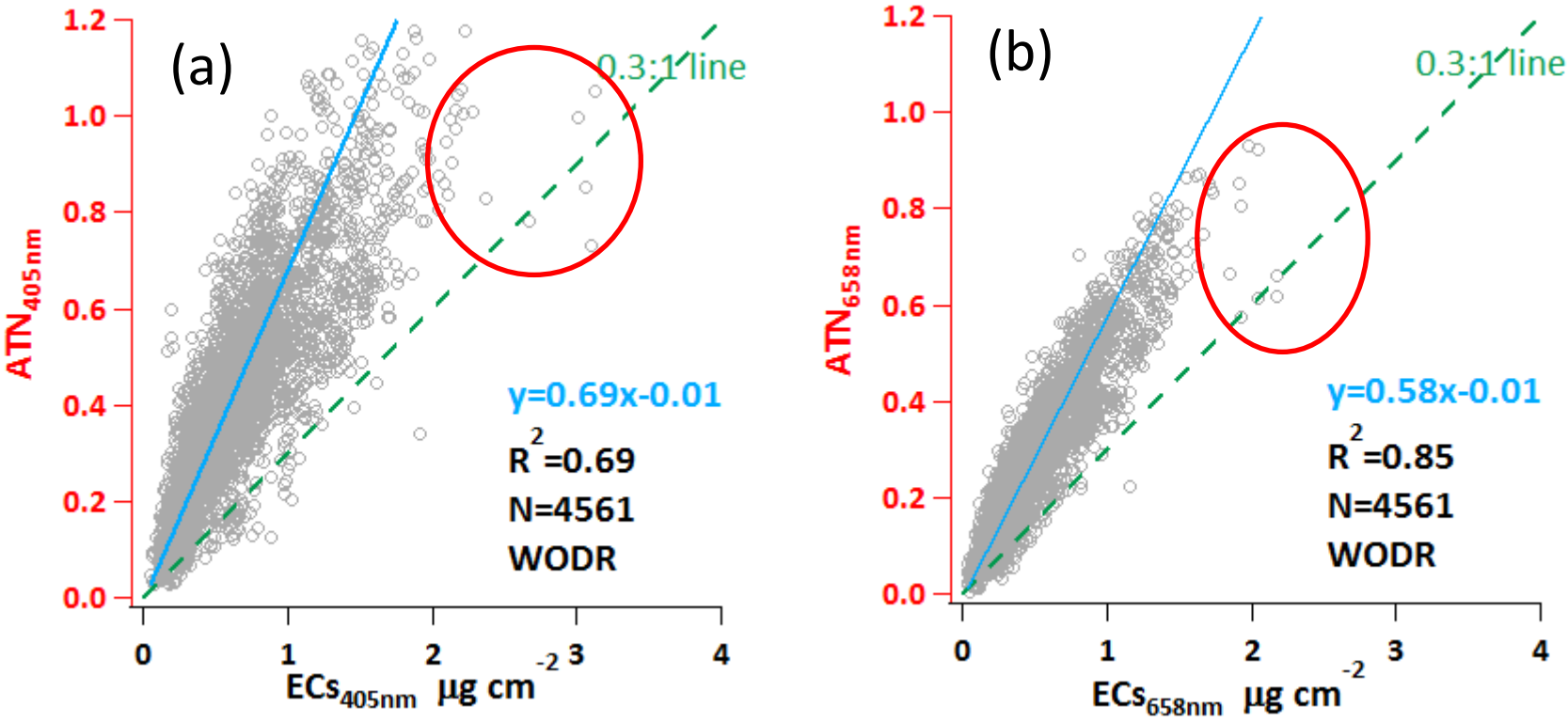


Fig.1 Dependence of light attenuation(ATN) at 405nm(a) and 658nm(b) on the EC loading(ECs).

Results and discussion

◆Variation of b_{abs}

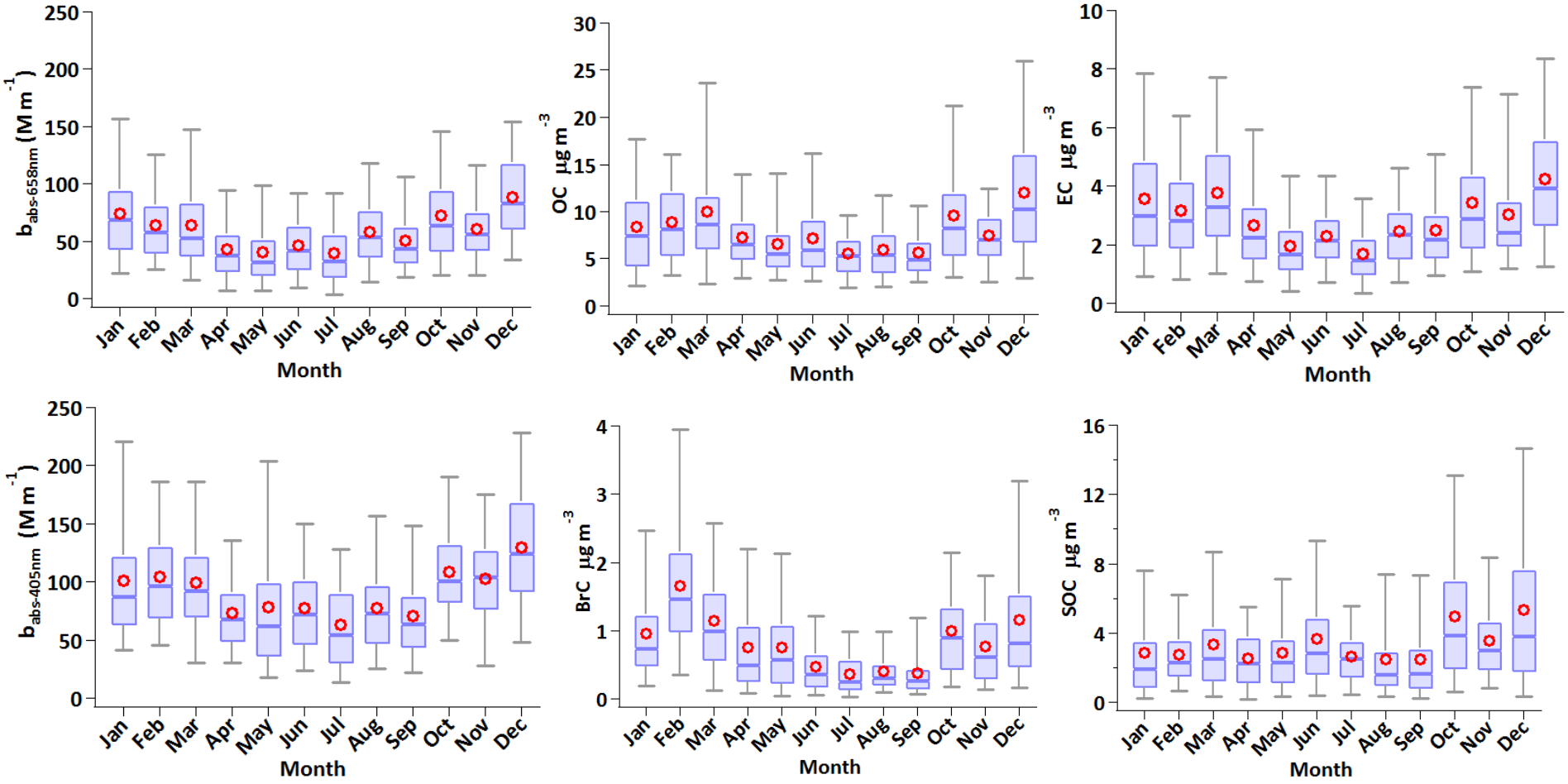


Fig.2 Temporal variation of $b_{abs-405nm}$, $b_{abs-658nm}$, OC, EC, BrC and SOC

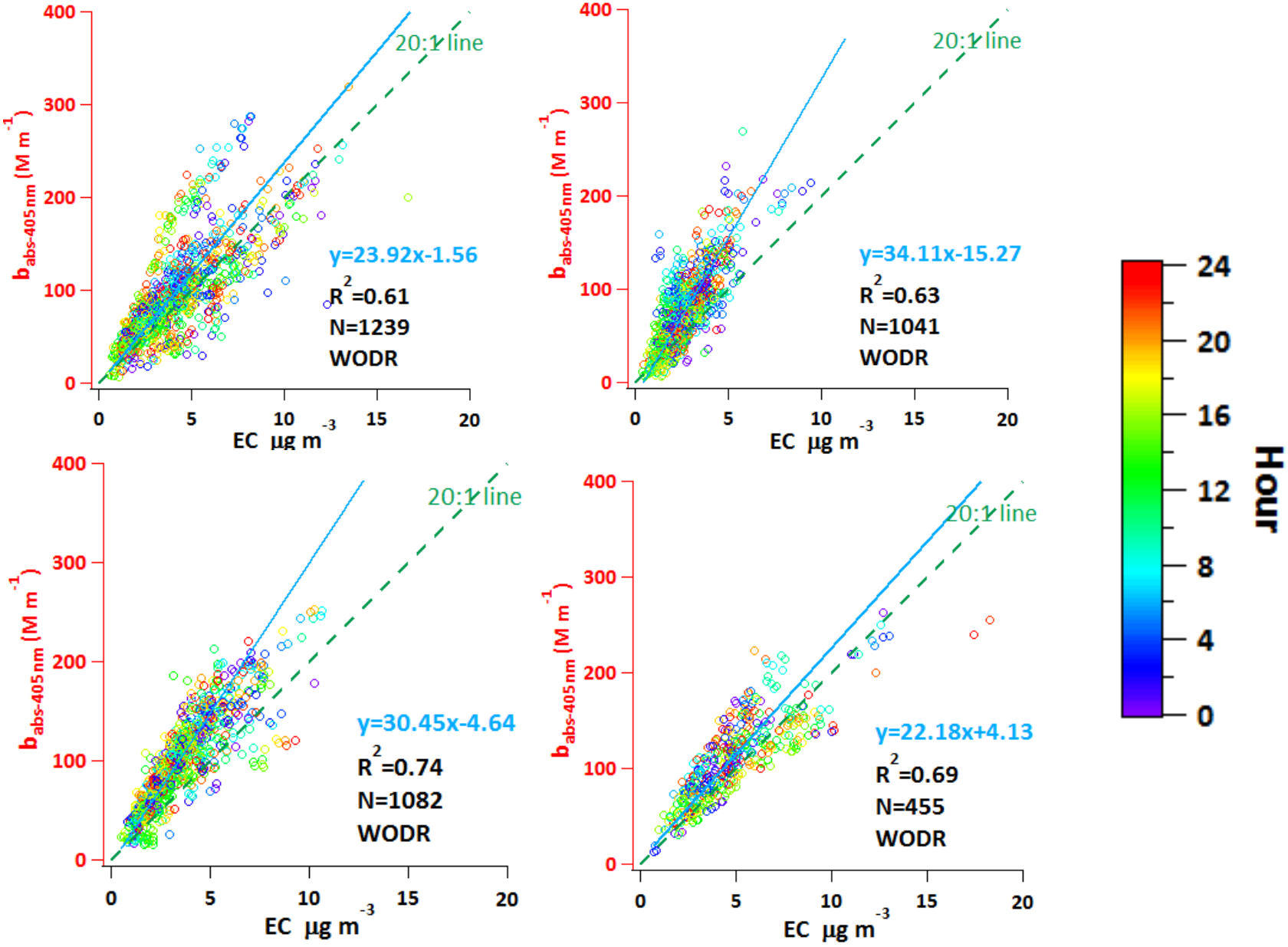


Fig.3 Correlation between $b_{abs\text{-}405nm}$ and EC.

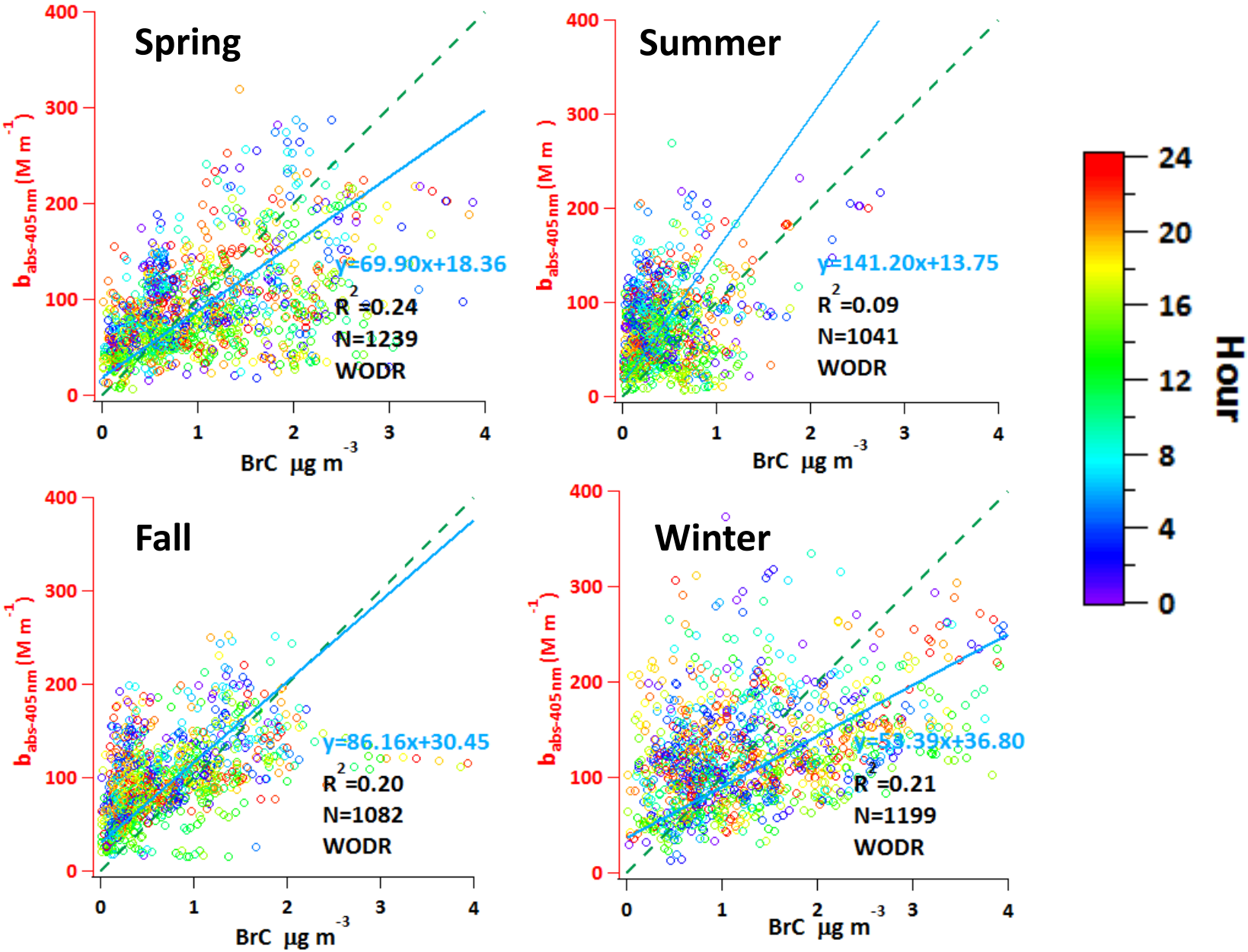


Fig.4 Correlation between $b_{abs\text{-}405nm}$ and BrC.

◆Variation of MAE

Vehicle emissions＞ Natural source

Fossil emission＞Biomass burning

(Zhang et al., 2011)

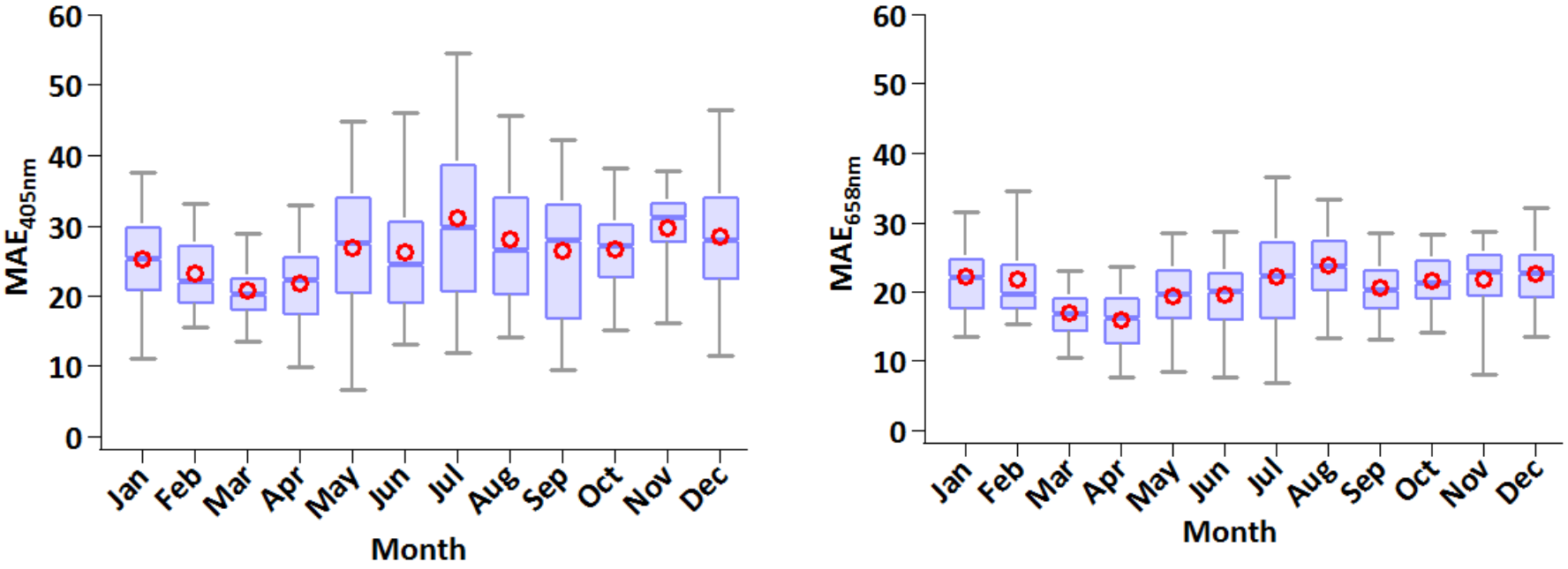


Fig.5 Temporal variation of MAE_{405nm} and MAE_{658nm}.

◆Variation of AAE

In field observations, AAE usually ranges from 0.55 to 1.7

(Bahadur et al., 2012; Gyawali et al., 2009; Lack and Langridge, 2013)

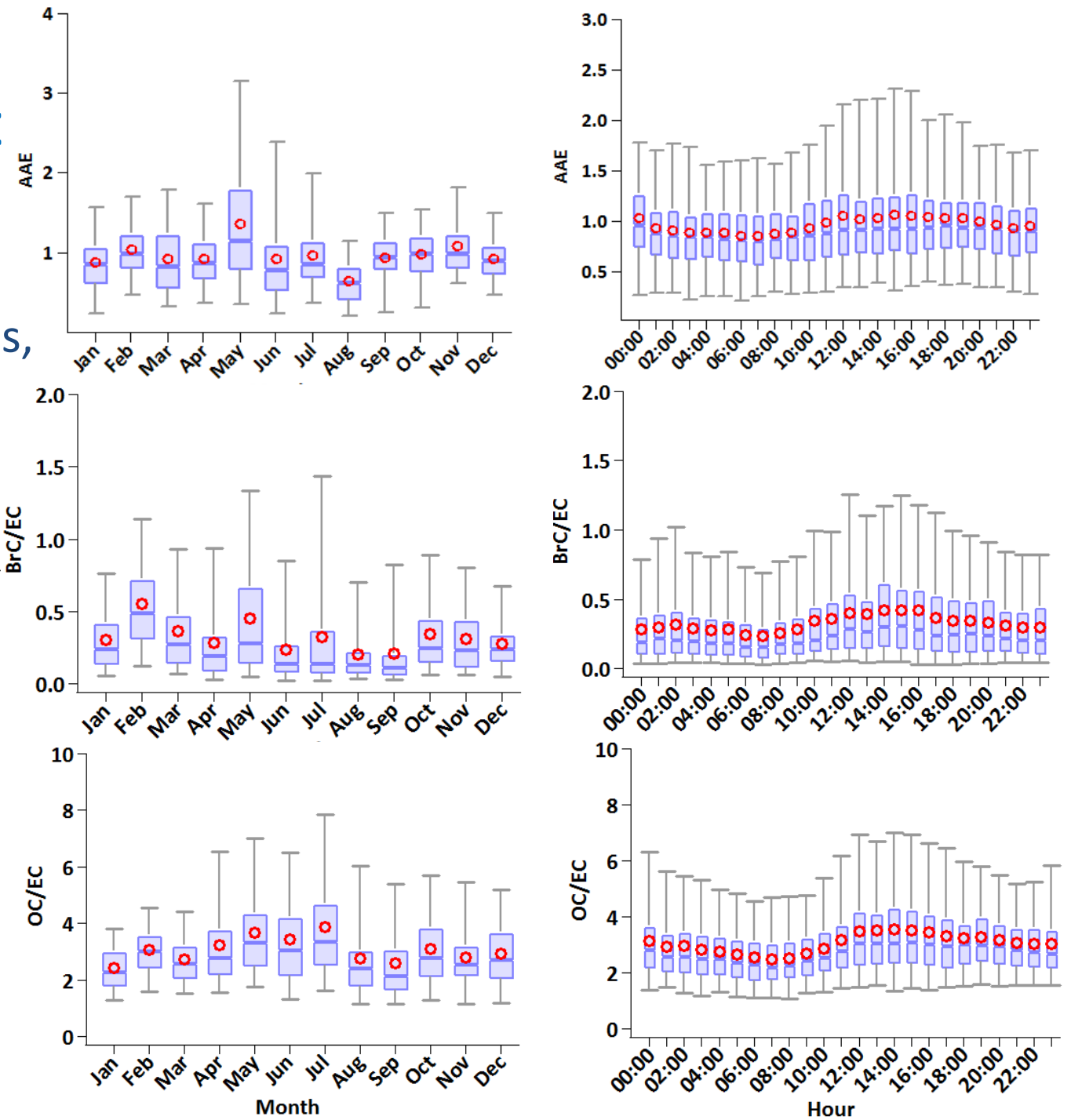


Fig.6 Monthly variation and diurnal variation of AAE, BrC/EC and OC/EC.

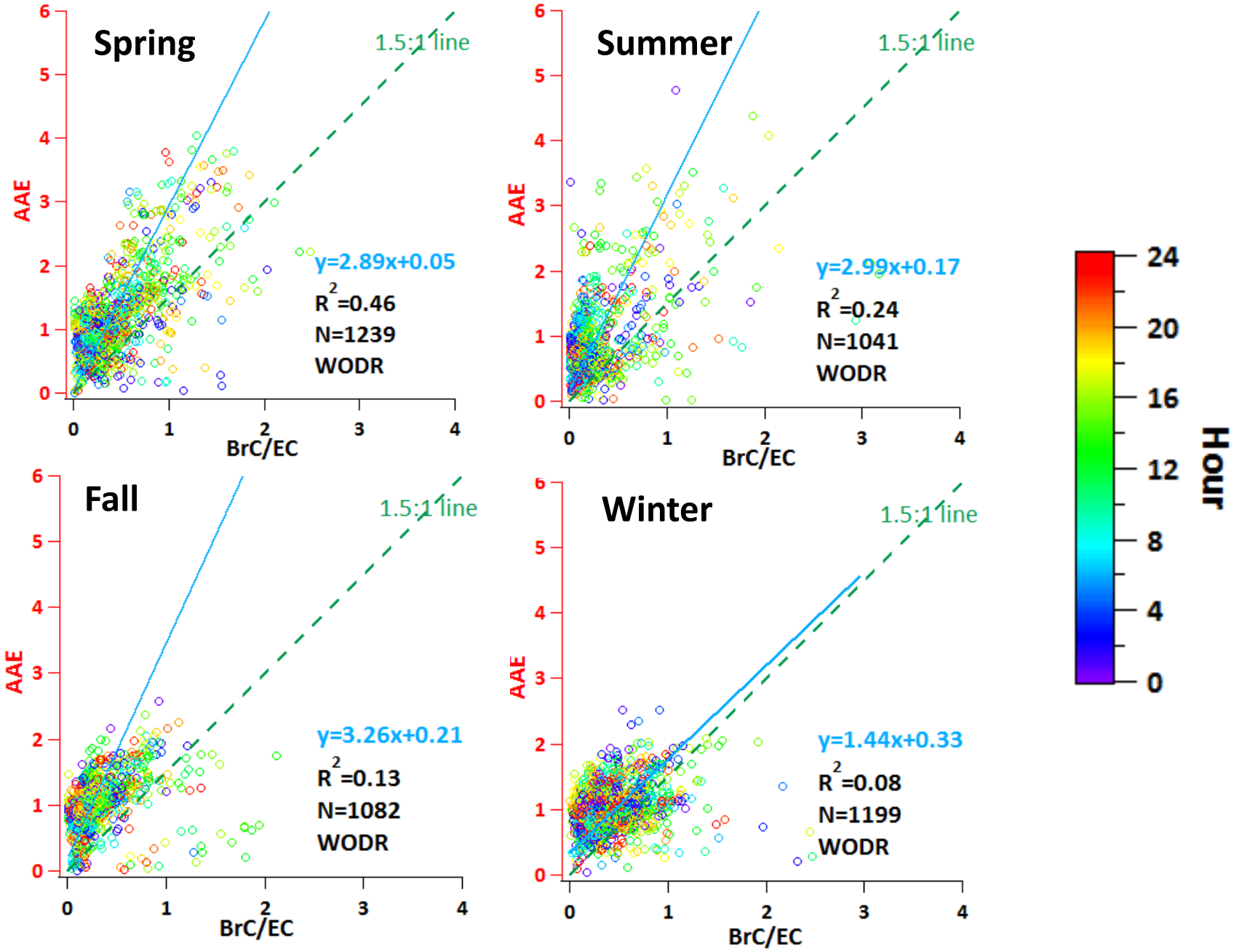


Fig.7 Correlation between $b_{abs\text{-}405nm}$ and BrC/EC.

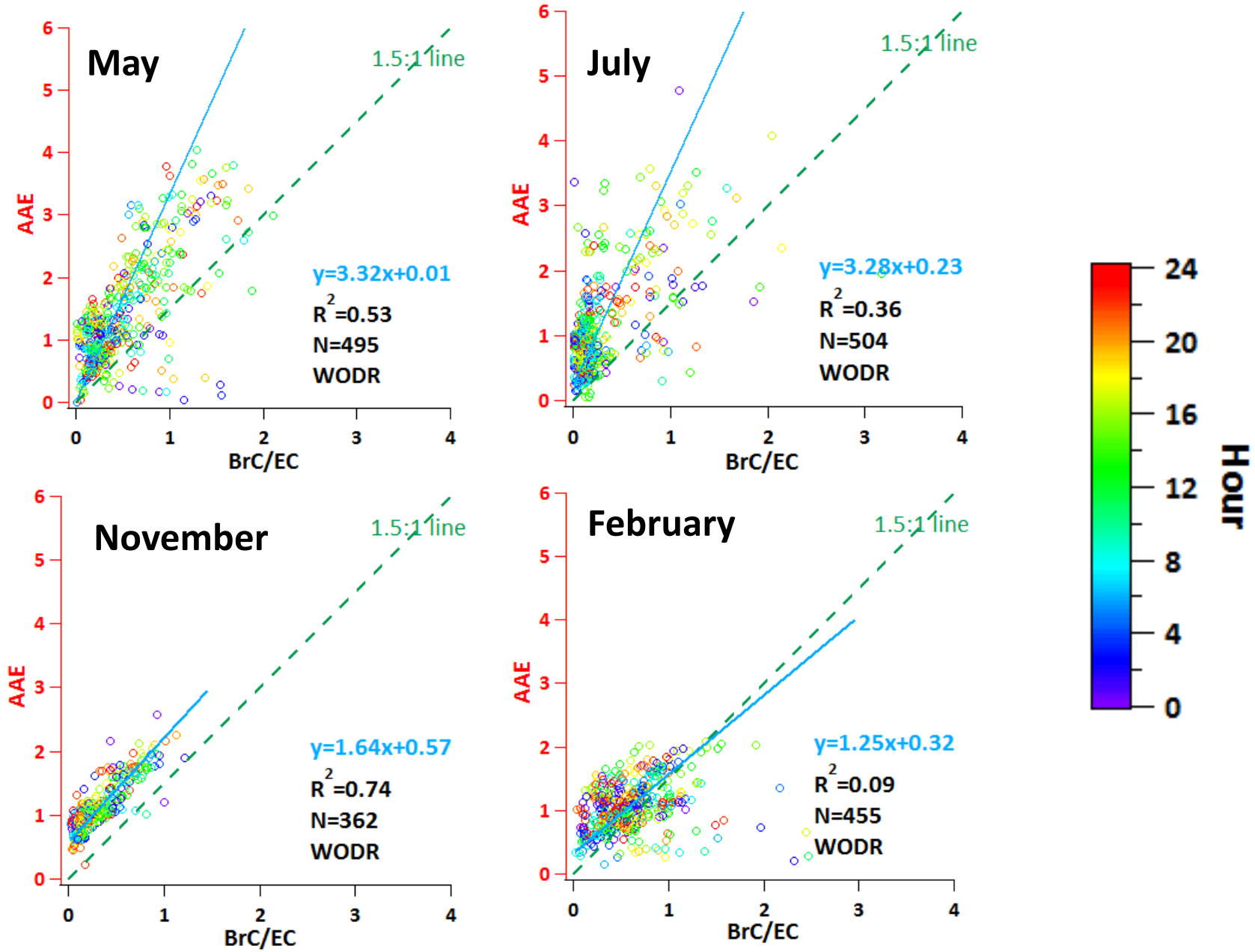


Fig.8 Correlation between $b_{abs\text{-}405nm}$ and BrC/EC.

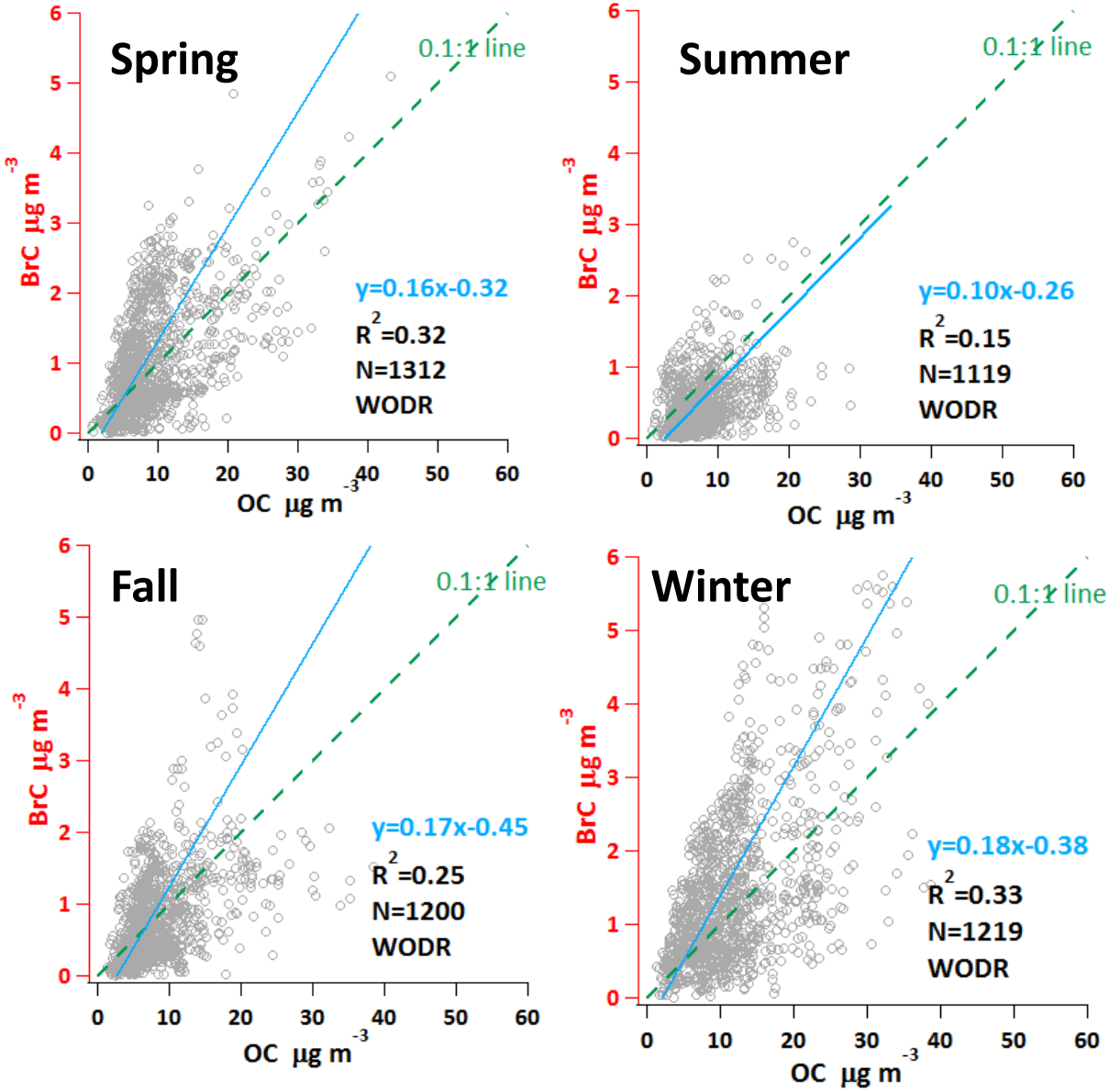


Fig.9 Correlation between BrC and OC.

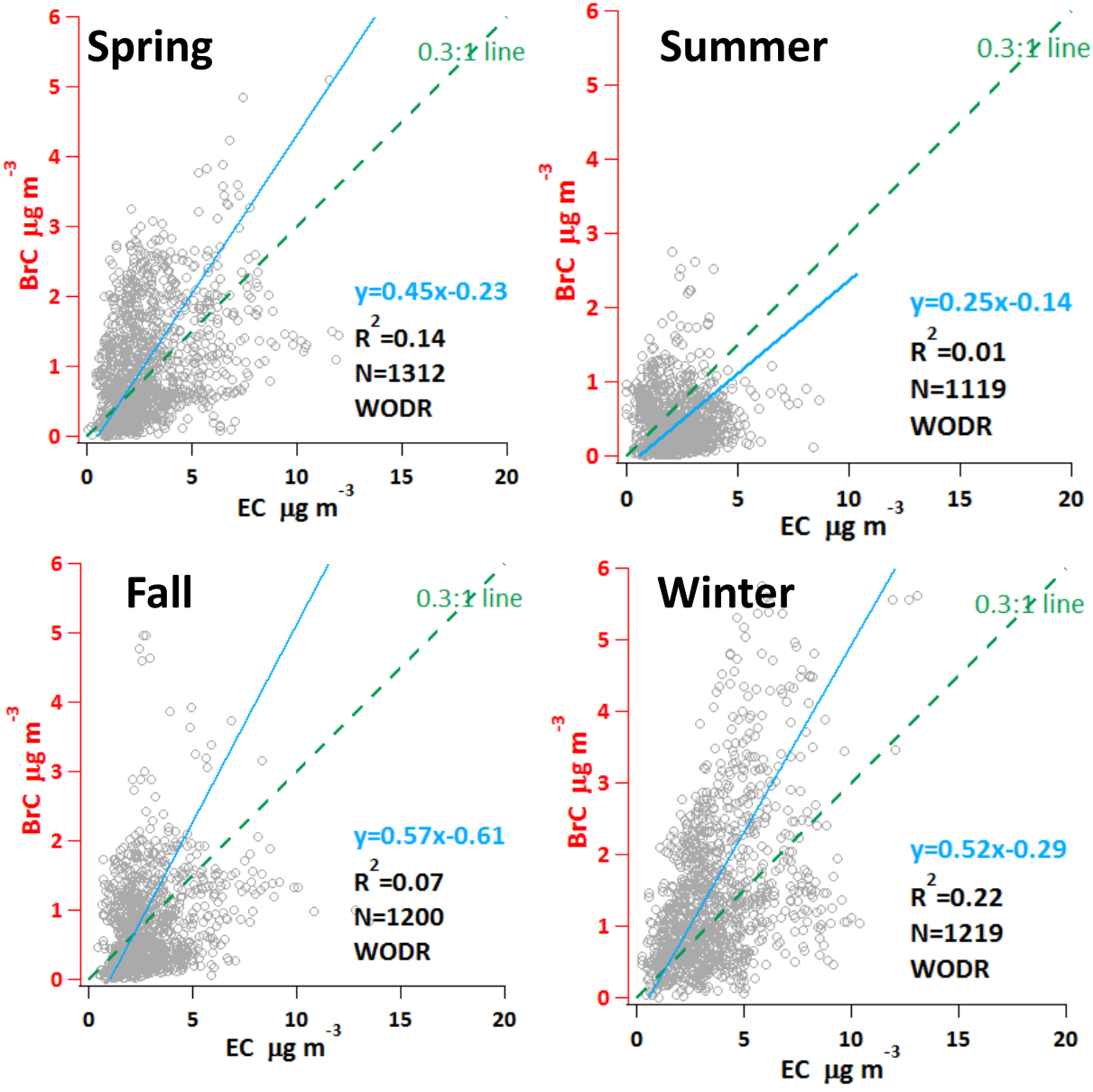


Fig.10 Correlation between BrC and EC.

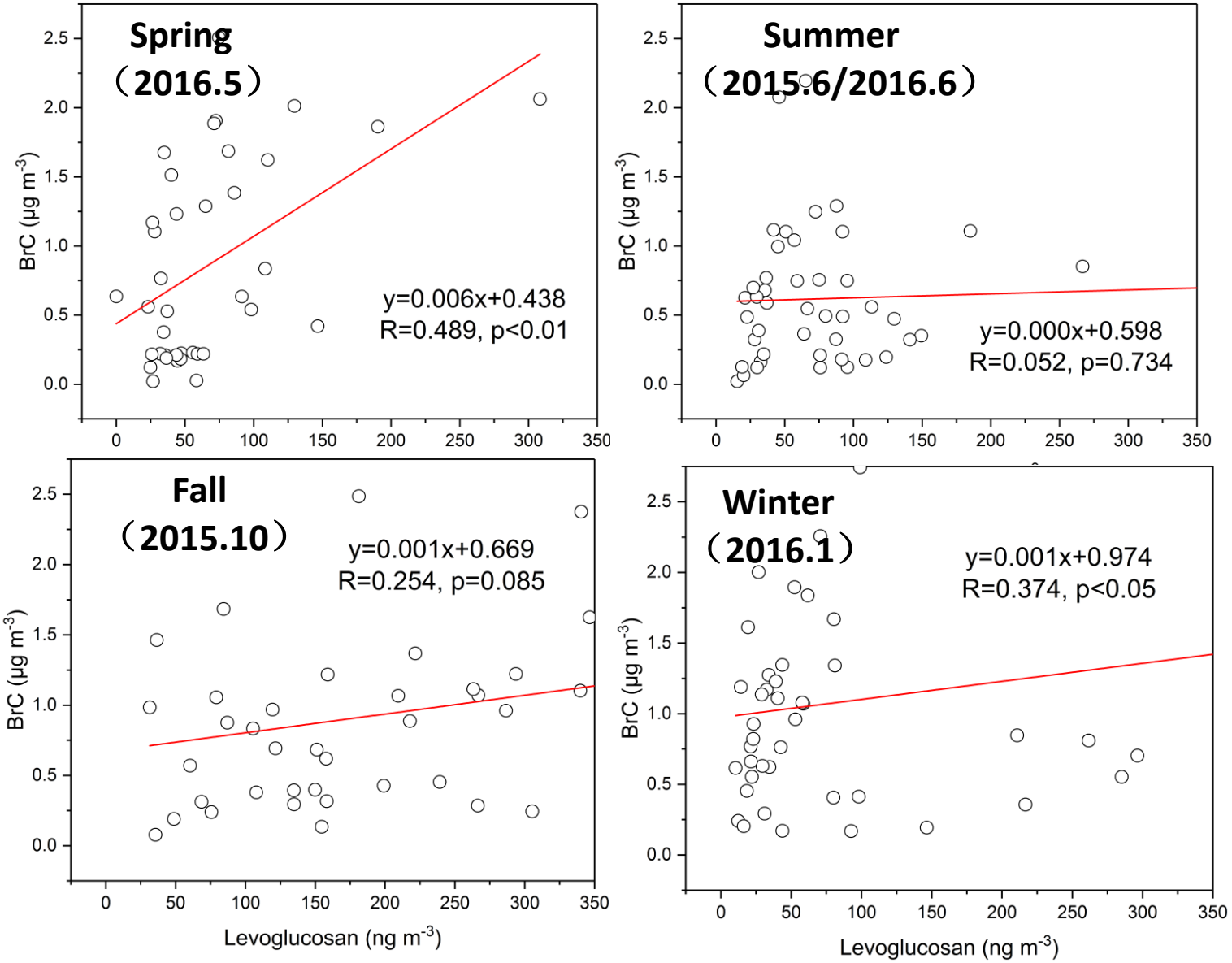


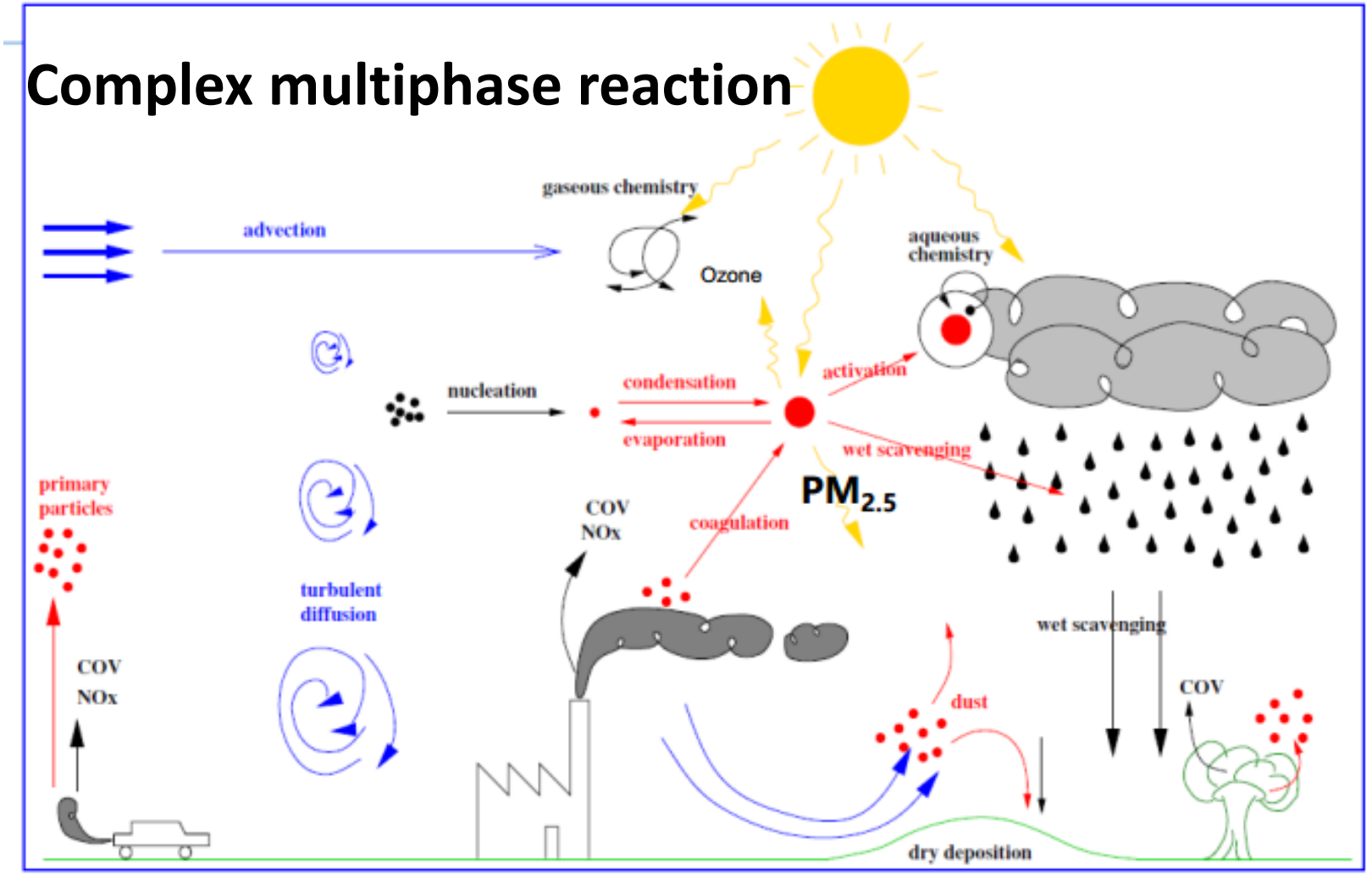
Fig.11 Correlation between BrC and Levoglucosan.

Conclusion

- The sources of BrC and OC, EC appeared obvious different. Biomass burning contributed to high BrC in Spring and no significant BrC formation was found in summer. During autumn and winter, the origins of BrC were complicated.

- The formation mechanism of BrC still needs to be study.

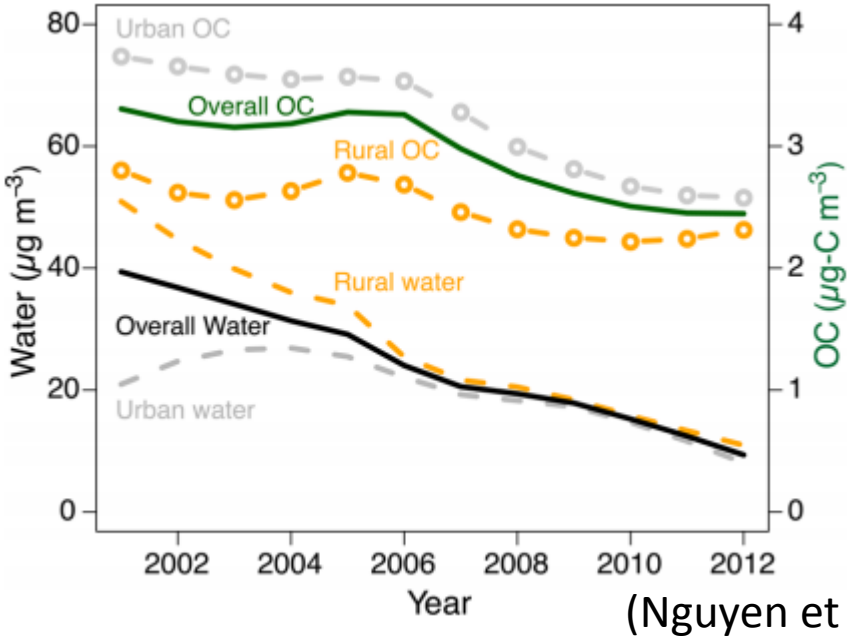
Outlook



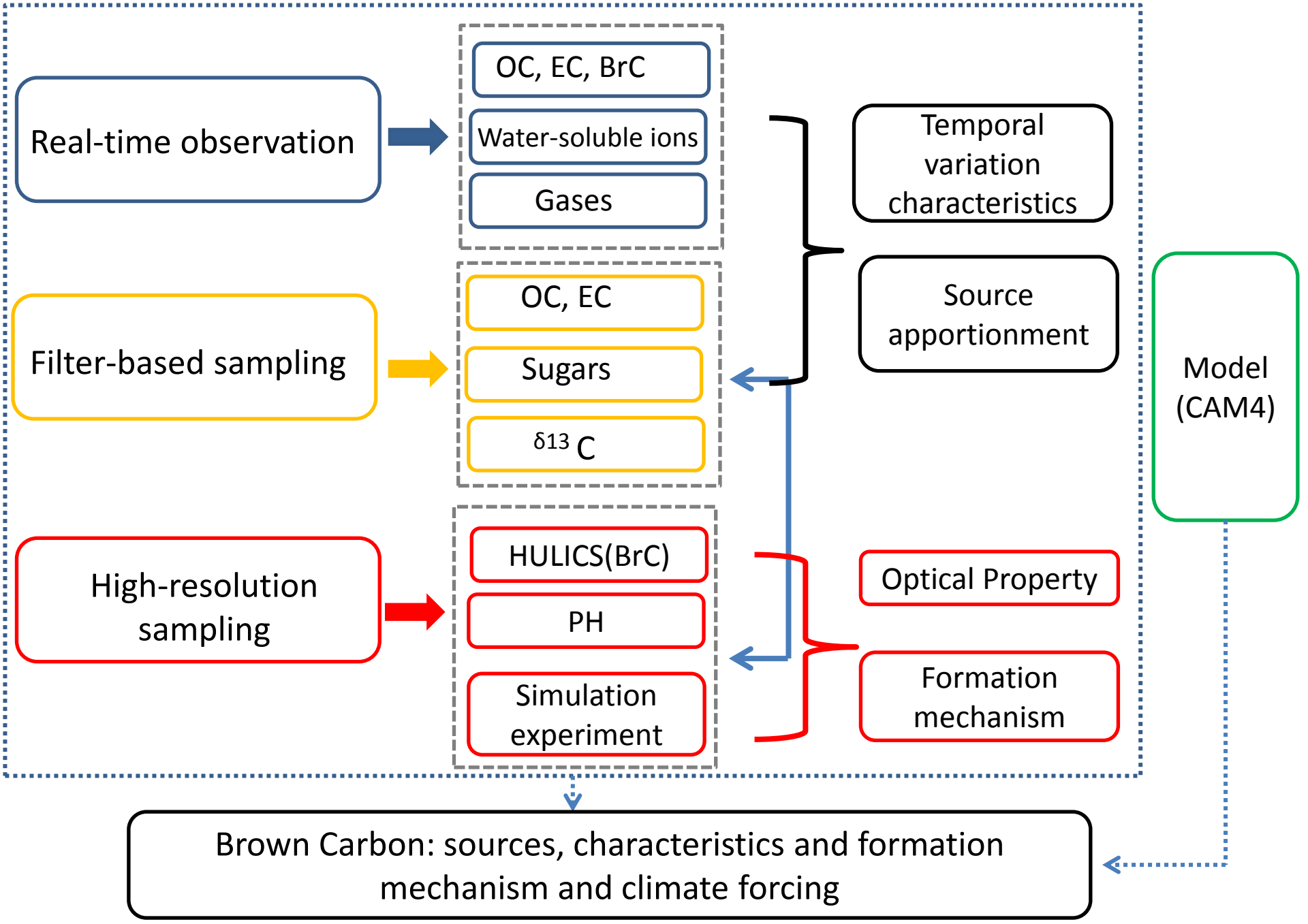
(Source: Chen Y, 2017)

Aqueous secondary organic aerosol(aqSOA)

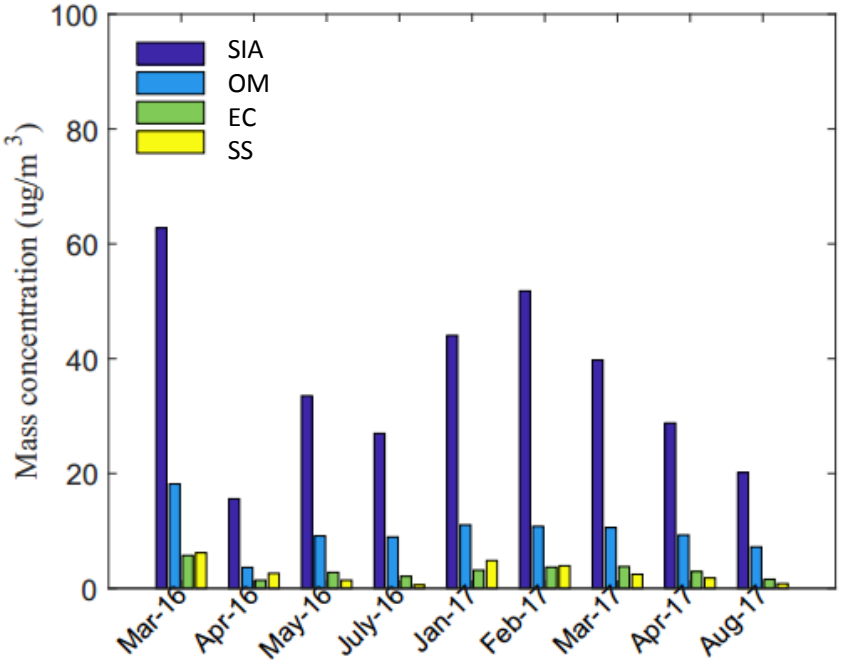
- Traditional models typically underpredict secondary organic aerosol (SOA) mass, suggesting that a complete knowledge of SOA formation mechanisms remains a major source of uncertainty. (Gilardoni et al., 2016)
- laboratory experiments and predictions suggest that water-soluble products from the gas-phase oxidation of VOCs can also partition into atmospheric waters (i.e., clouds, fogs, and aerosol water) and react to form low volatility products. These products can remain in the particle phase after water evaporation, forming what is termed aqueous secondary organic aerosol (aqSOA).(Sullivan et al., 2016)



(Nguyen et al., 2015)


Real-time observation
OC, EC, BrC
Water-soluble ions
Gases
Filter-based sampling
OC, EC
Sugars
δ13 C
High-resolution sampling
HULICS(BrC)
PH
Simulation experiment
Temporal variation characteristics
Source apportionment
Optical Property
Formation mechanism
Model (CAM4)
Brown Carbon: sources, characteristics and formation mechanism and climate forcing

Chemical content of $PM_{2.5}$ in Nanjing



（Sources: Xu L, 2017）

[Sulfate]=1.375*[SO_4^{2-}]

[Nitrate]=1.29*[NO_3^-]

[SIA]=[Sulfate]+[Nitrate] Tao et al., 2013

[OM]=1.6*[OC] Zhang et al., 2013

[Sea salt]=1.82*[Cl^-] Pitchford et al., 2007

Aerosol Water in Shanghai

◆ Liquid Water Content(LWC)

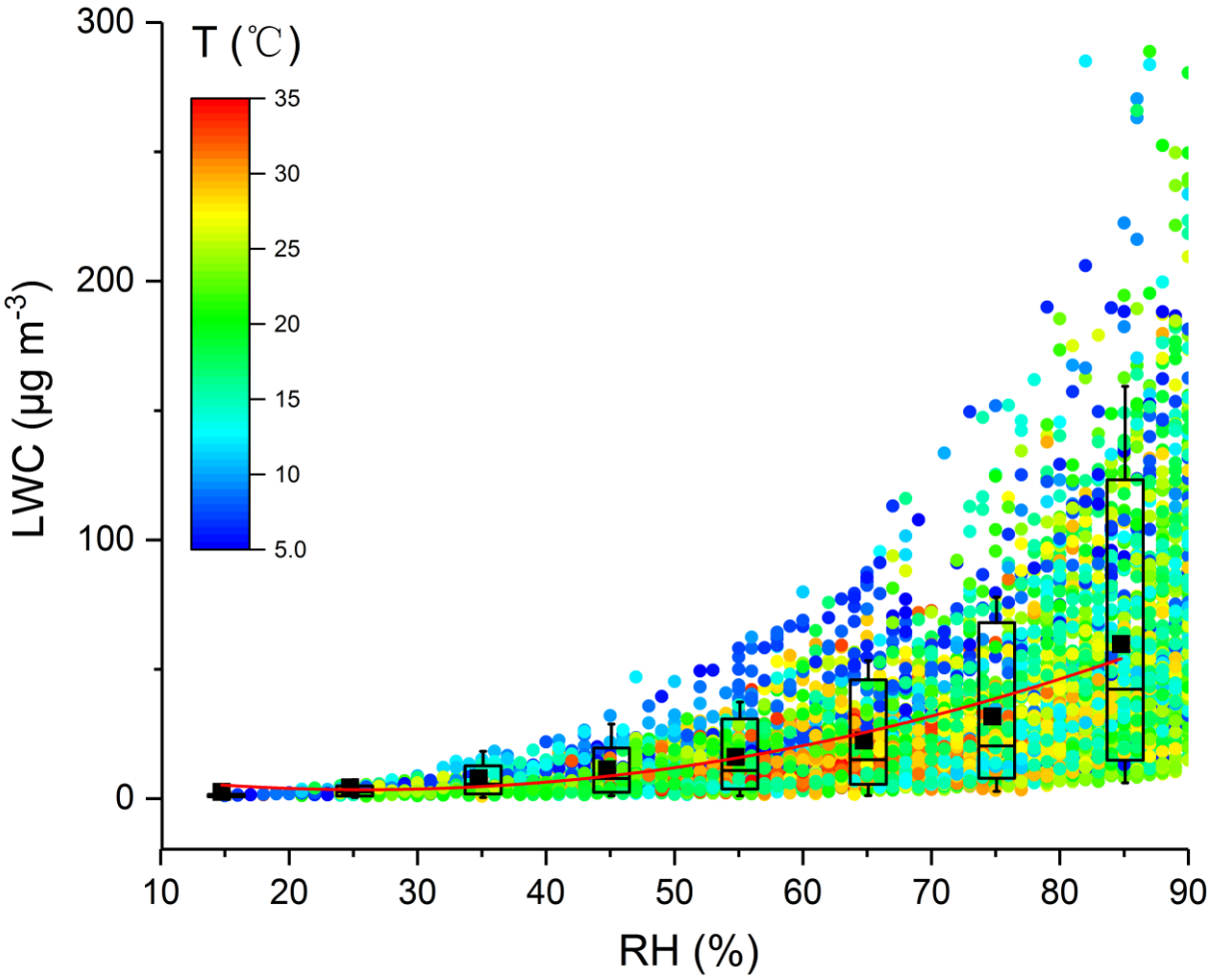


Fig.12 LWC concentrations under different relative humidities.

Aerosol Water in Shanghai

◆ Correlation between Liquid Water Content(LWC) and OC, SO_4^{2-}, NO_3^-

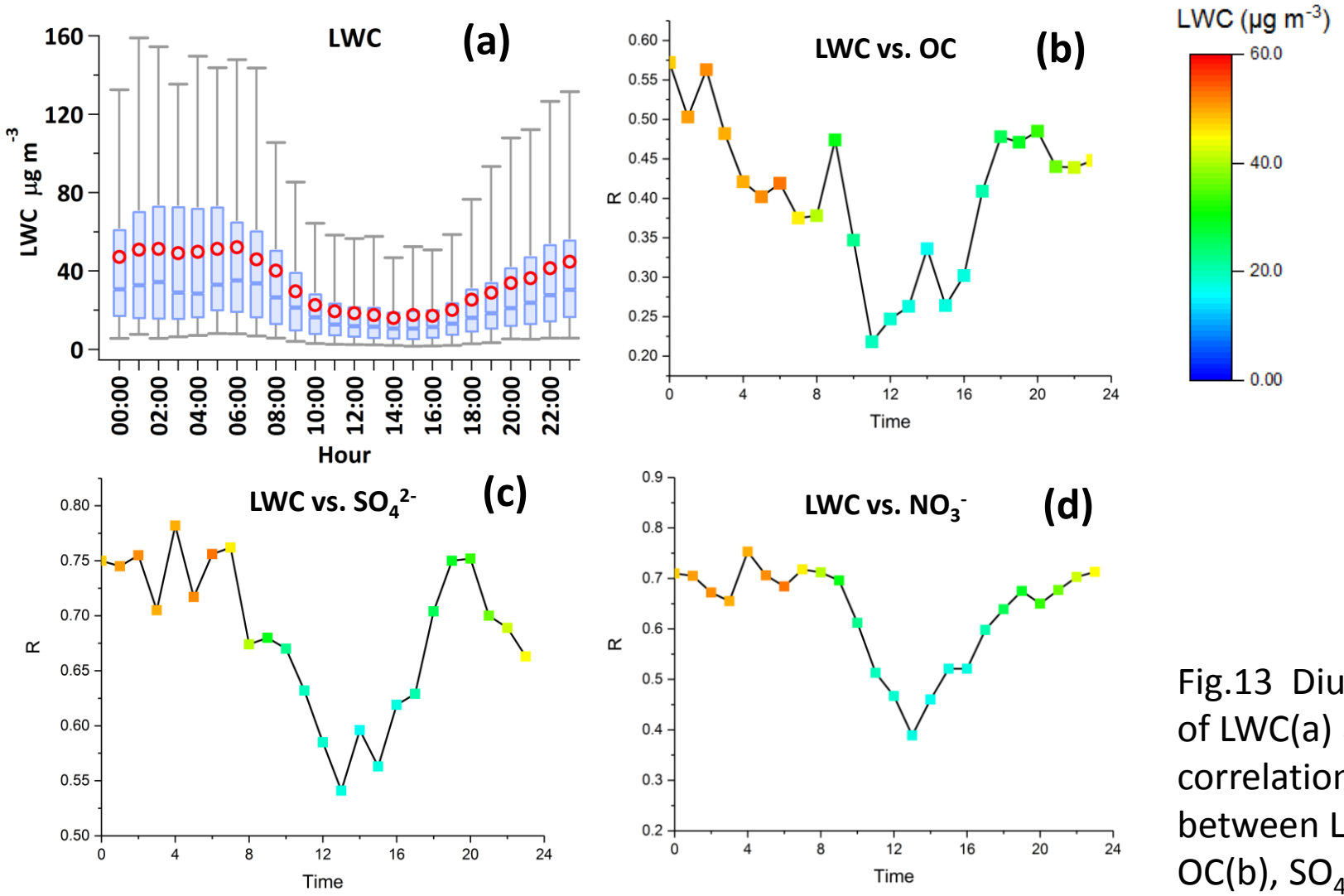


Fig.13 Diurnal patterns of LWC(a) and the correlation coefficient between LWC and OC(b), SO_4^{2-}(c), NO_3^-(d).

References

Shen G, Chen Y, Wei S, et al. Mass absorption efficiency of elemental carbon for source samples from residential biomass and coal combustions[J]. **Atmospheric Environment**, 2013, 79(11):79-84.

Ram K, Sarin M M. Absorption coefficient and site-specific mass absorption efficiency of elemental carbon in aerosols over urban, rural, and high-altitude sites in India.[J]. **Environmental Science & Technology**, 2009, 43(21):8233-9.

Cheng Y, He K B, Zheng M, et al. Mass absorption efficiency of elemental carbon and water-soluble organic carbon in Beijing, China[J]. **Atmospheric Chemistry & Physics**, 2011, 11(22):24727-24764.

Srinivas B, Sarin M M. Brown carbon in atmospheric outflow from the Indo-Gangetic Plain: Mass absorption efficiency and temporal variability[J]. **Atmospheric Environment**, 2014, 89(2):835-843.

Zhang X, Lin Y, Surratt J D, et al. Light-absorbing soluble organic aerosol in Los Angeles and Atlanta: A contrast in secondary organic aerosol[J]. **Geophysical Research Letters**, 2011, 38(21):759-775.

Gilardoni S, Massoli P, Paglione M, et al. Direct observation of aqueous secondary organic aerosol from biomass-burning emissions[J]. **Proceedings of the National Academy of Sciences of the United States of America**, 2016, 113(36):10013.

Nguyen T K V, Capps S L, Carlton A G. Decreasing Aerosol Water Is Consistent with OC Trends in the Southeast U.S.[J]. **Environmental Science & Technology**, 2015, 49(13):7843-50.

Yale 耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

Thank you!