Yale-NUIST Center on Atmospheric Environment

Chemical characterization, source apportionment and light absorption analysis of $PM_{2.5}$ in Nanjing: seasonal perspective

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Outline

- Introduction
- Methodology
- Results and discussion
- Conclusion
- Next step

Introduction

Severe aerosol pollution in eastern China

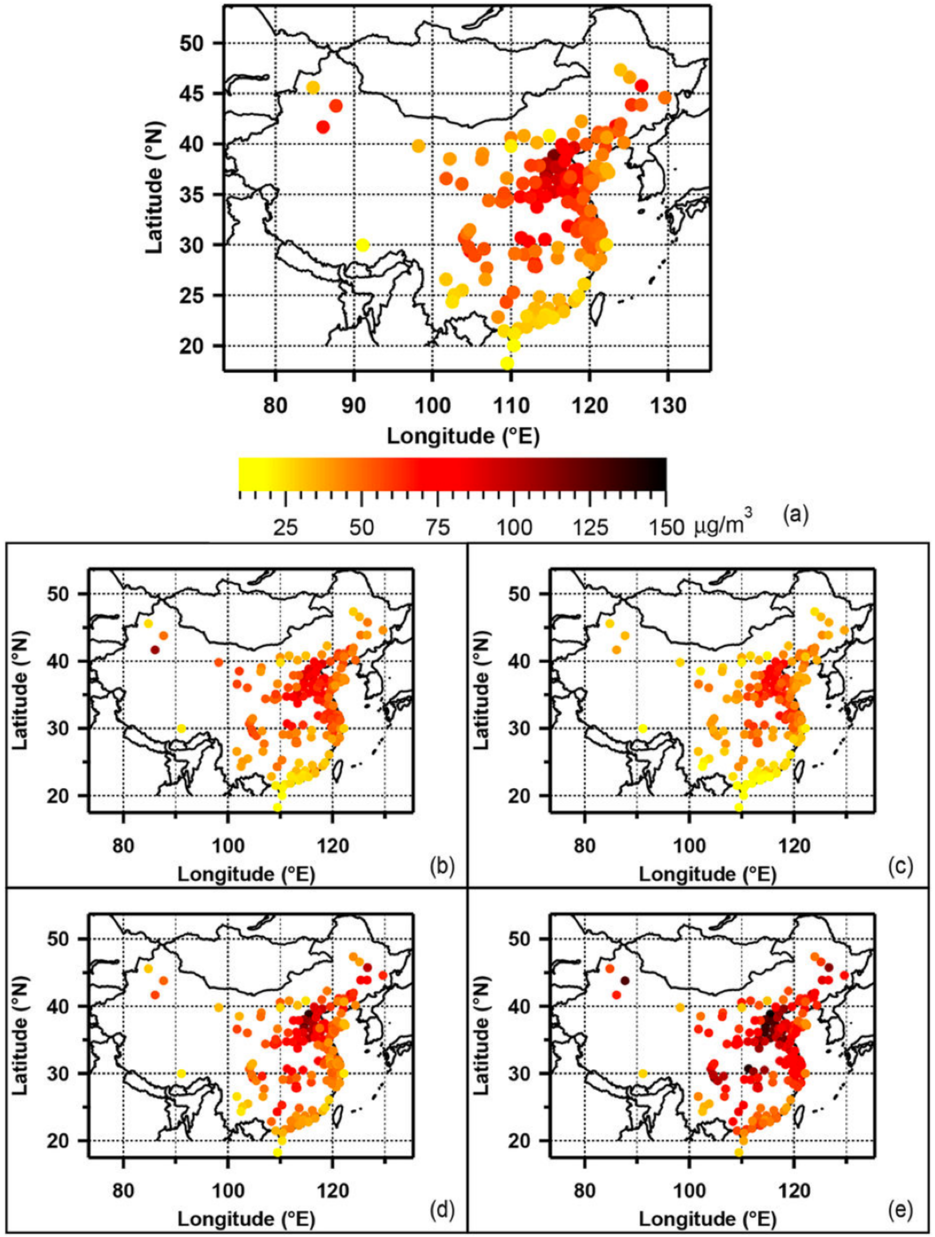


Figure 1 : The averaged $PM_{2.5}$ concentrations ($\mu g/m^3$) of the 190 cities of China, during the year of 2014/2015 (a) and during the spring (b), summer (c), autumn (d), and winter (e).

(Zhang, et al., 2015)

Complex aerosol sources

industry emission

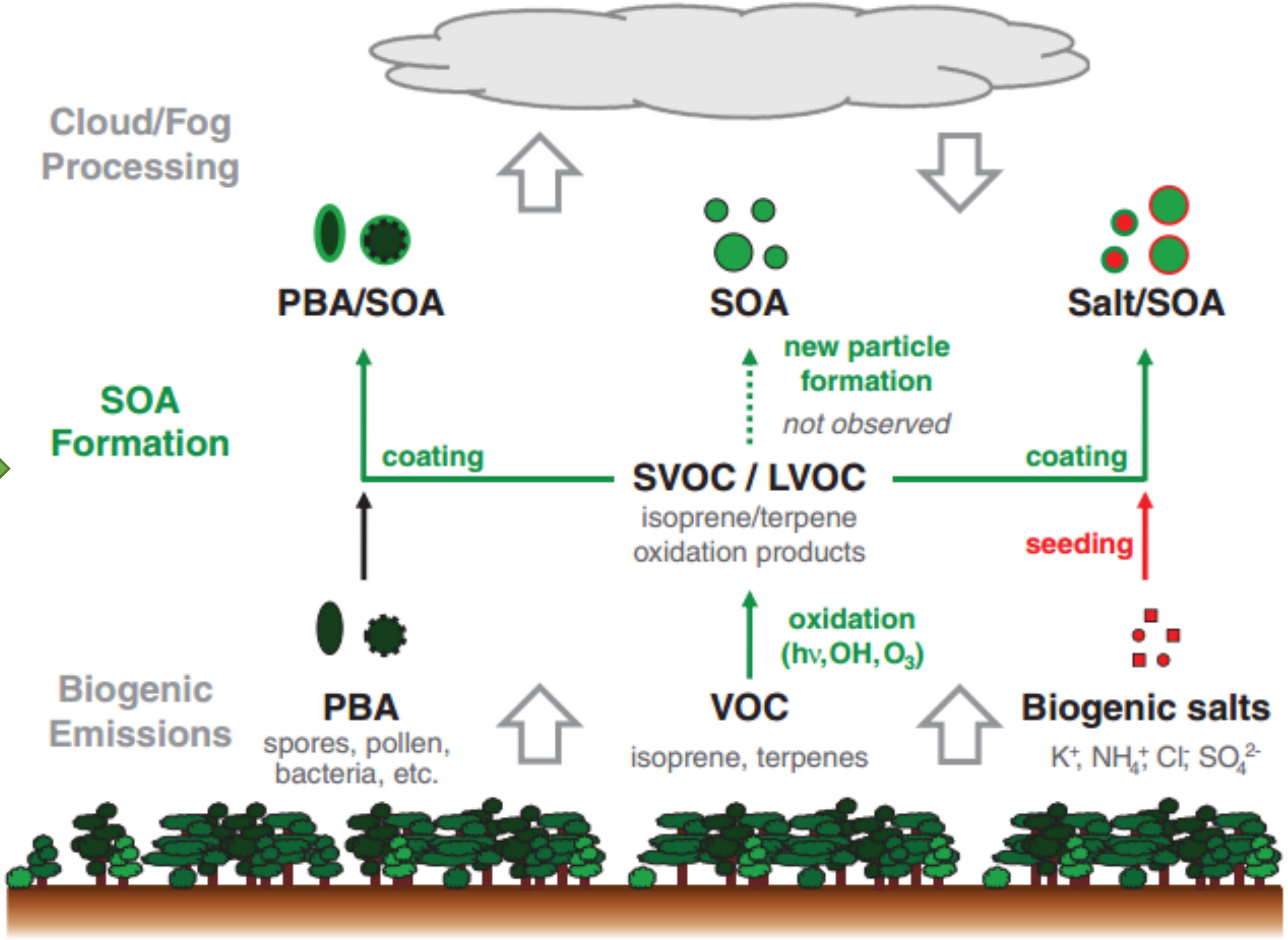
Sea salt

traffic emission

Biogenic emission

Biomass burning

dust



(Pöhlker, et al., 2012)

Light-absorbing aerosol

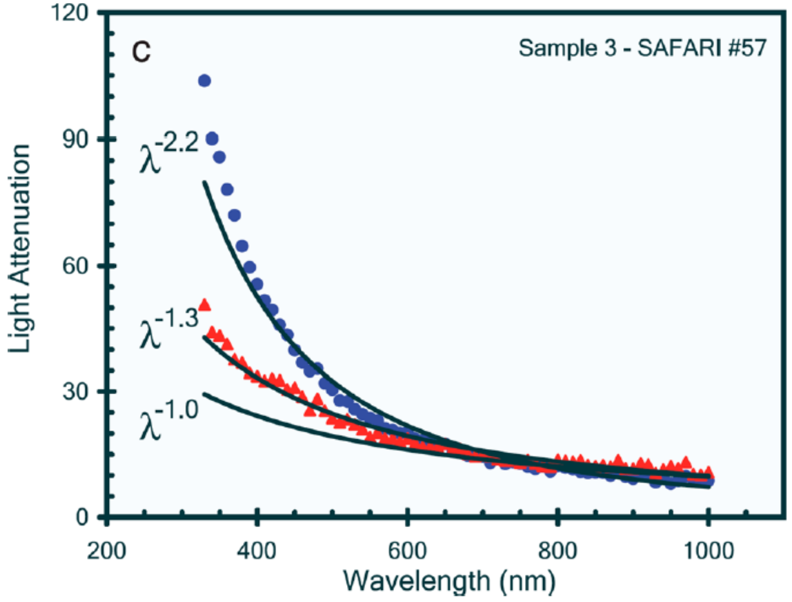
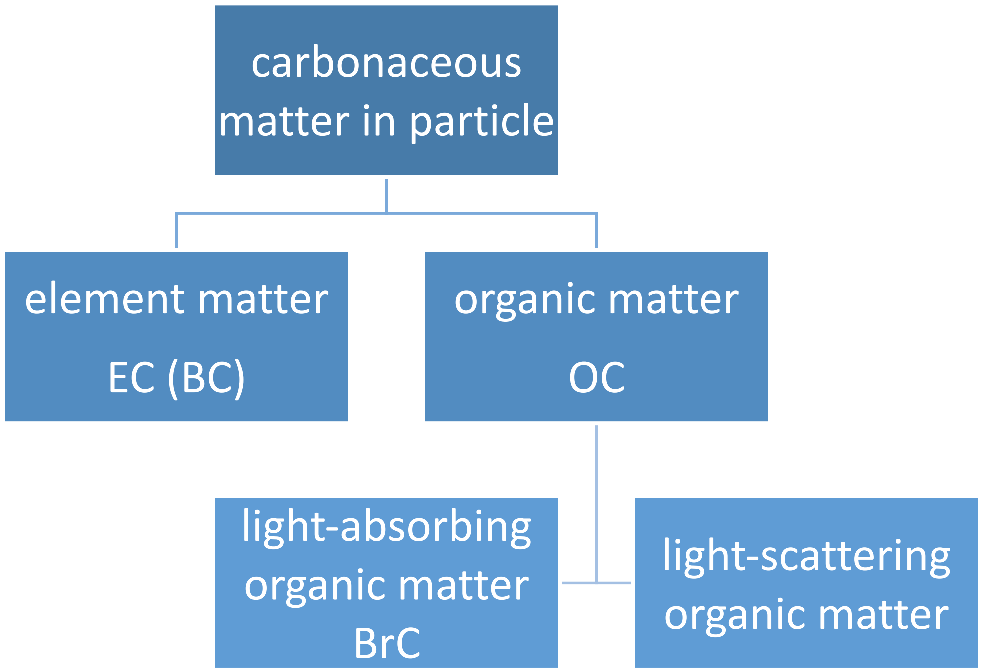


Figure. 3 Measured light attenuation from an untreated sample of biomass-burning aerosol from savanna fires in Africa. Circles (blue) indicate an untreated sample, and triangles (red) denote a sample with organic constituents removed by acetone extraction. Abosorbtion Angström exponents (AAE) = 1, BC ; AAE > 1, BrC .

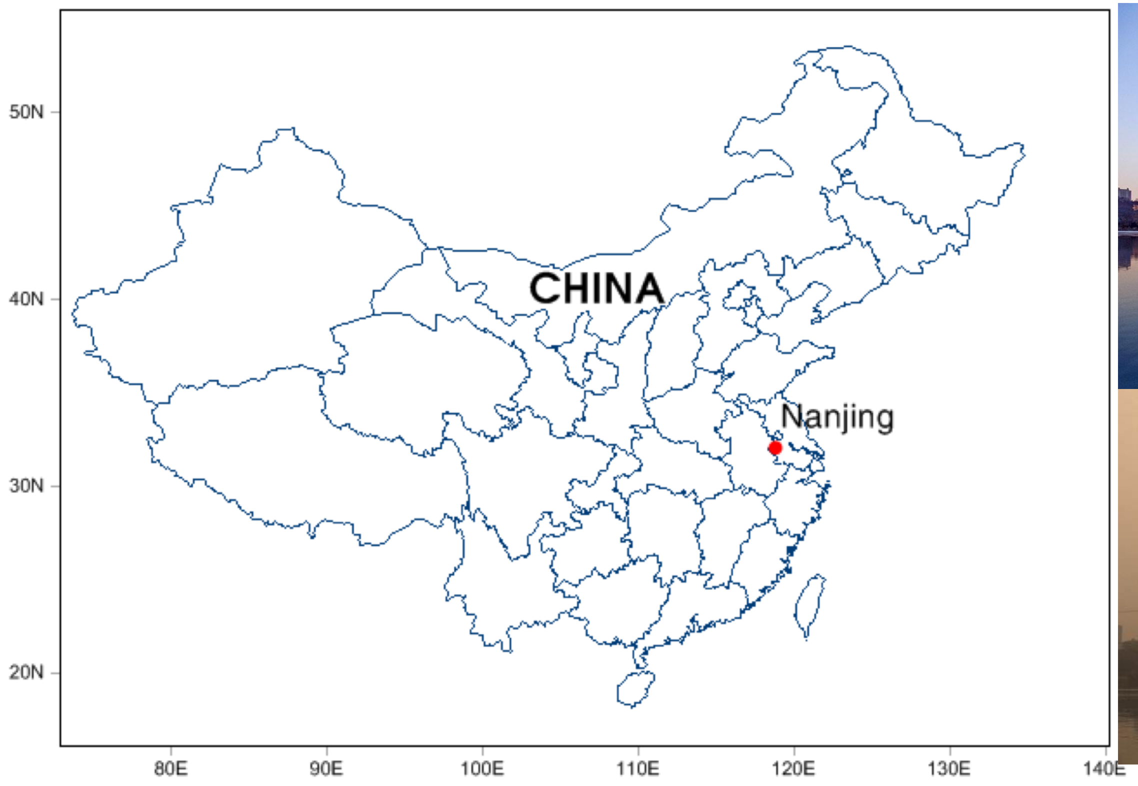
(Kirchstetter et al., 2004)



(Healy R M et al., 2015; Feng Y et al., 2013; Cheng et al., 2016)

Methodology

Study area



Sample collection method:

Time	Sampler	Particle size	Frequency	Number of samples
2015 summer 2015 autumn 2015-2016 winter 2016 spring	KC 6120	$PM_{2.5}$	12 hr	~60 per season

Sample chemical analysis:

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

PMF model

$$X_{ij} = \sum_{k=1}^{p} G_{ik} F_{kj} + E_{kj}$$ **(predicted concentration)**

where X_{ij} **(observed concentration)** is the j th species concentration in the i th sample of the original data set, G_{ik} **(Contribution)** is the contribution of the k th factor to the i th sample, F_{kj} **(Profile)** is the fraction of the k th factor resulting from species j , and E_{ij} **is the residual** between the measured and estimated X_{ij} values through p **(number of factors)** principal components. In addition:

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{m} \left[\frac{X_{ij} - \sum_{k=1}^{p} G_{ik} F_{ik}}{U_{ij}} \right]^2$$

where U_{ij} **is the uncertainty (constant percent*concentration)** of the j th species in the i th sample of the original data set comprised of m **species** and n **samples**, and Q **(critical parameter of PMF)** is the weighted sum of squares of differences between the PMF output and the original data set. The PMF solution minimizes object function Q.

Number of runs : at least 20

Reference standard

Factor number is set by the operator before running the model. To pick up an optimum solution, there is other reference standard:

- observed concentration and modeled concentration correlate strongly (R^2) with a slope close to 1.
- factors fingerprint can be explained by physical knowledge.

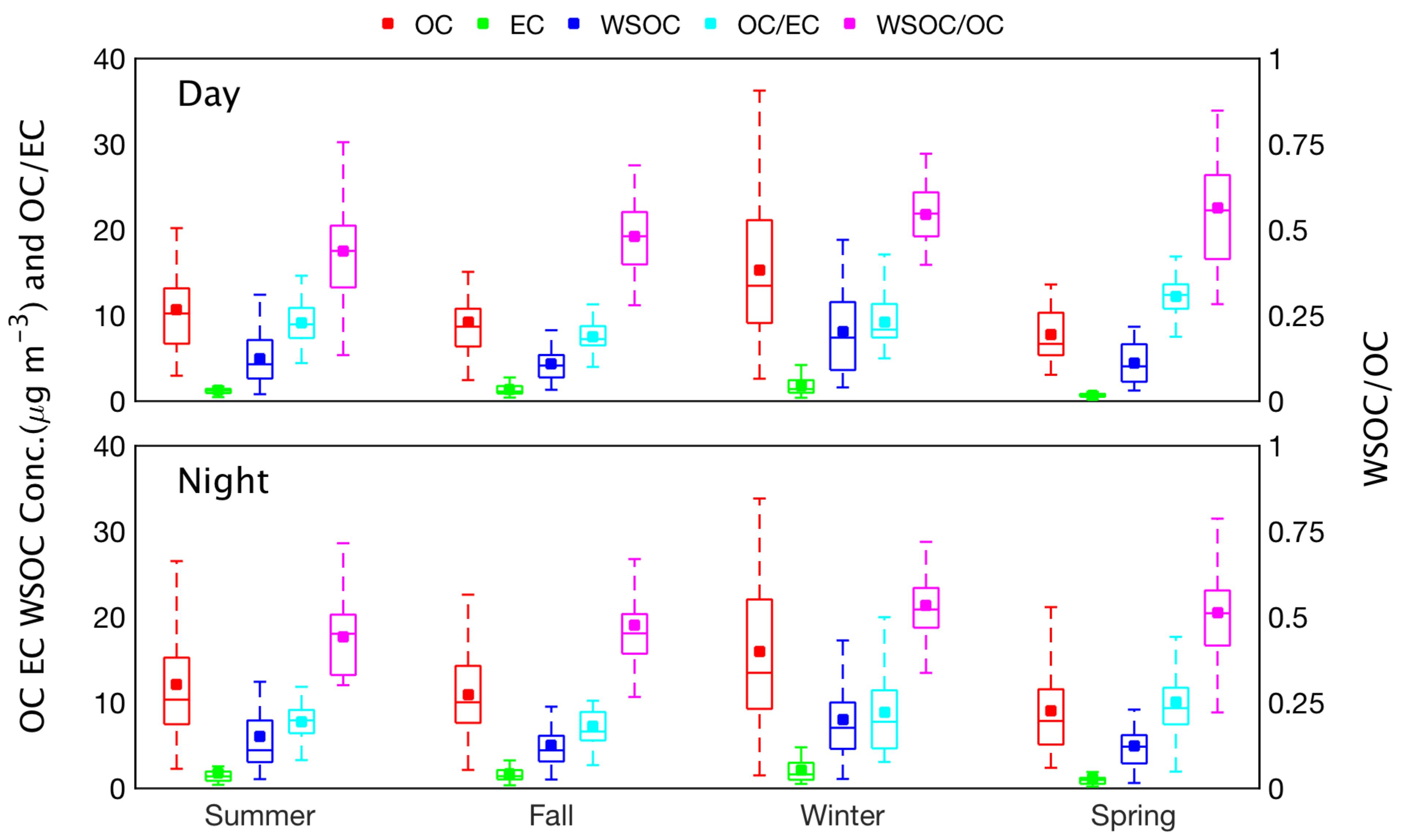
Limits of PMF:

- It's just a mathematical statistic calculation without considering physical or chemical background.

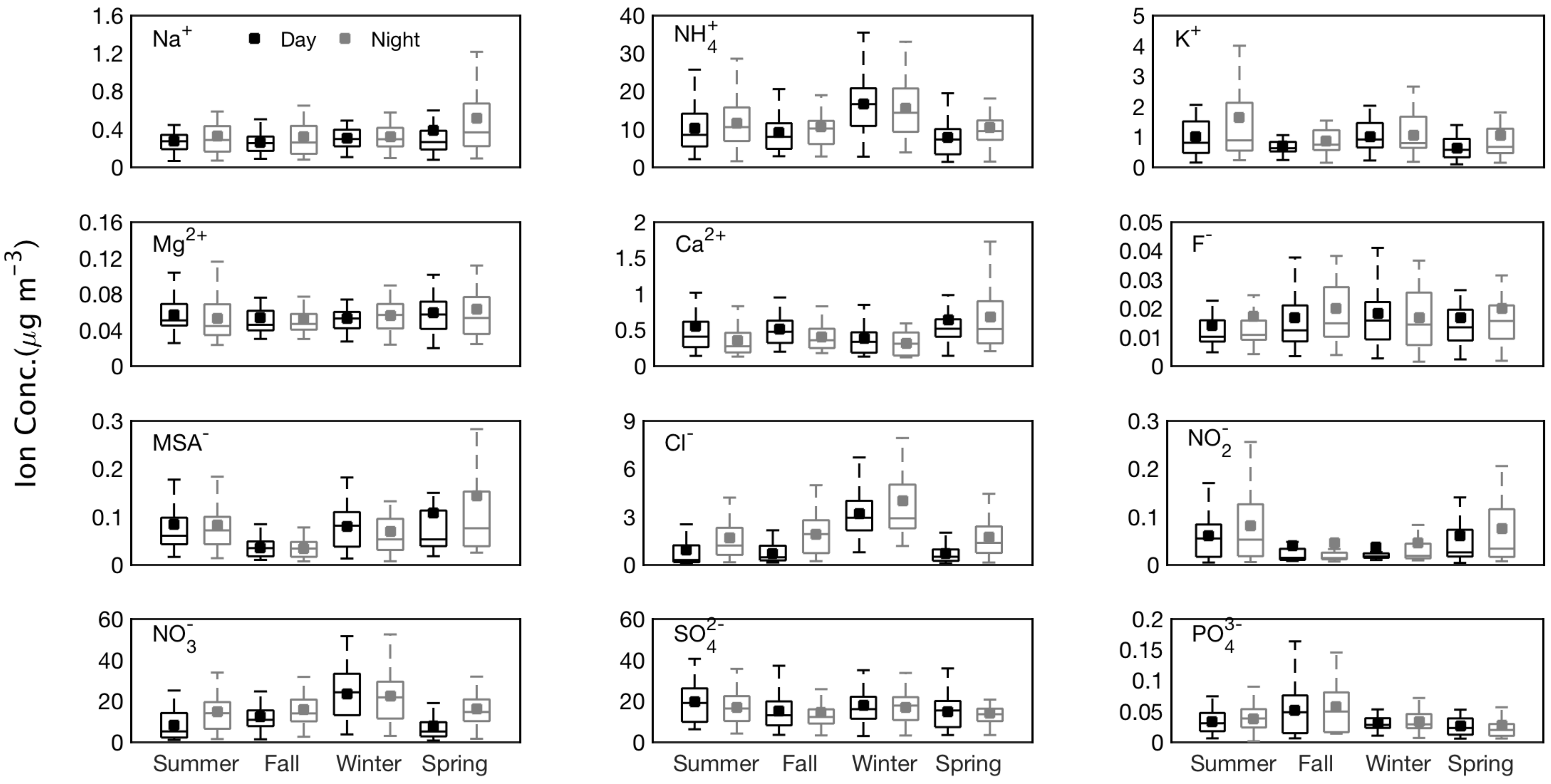
Results and discussion

- Chemical characteristics
- Source apportionment
- Light-absorbing property

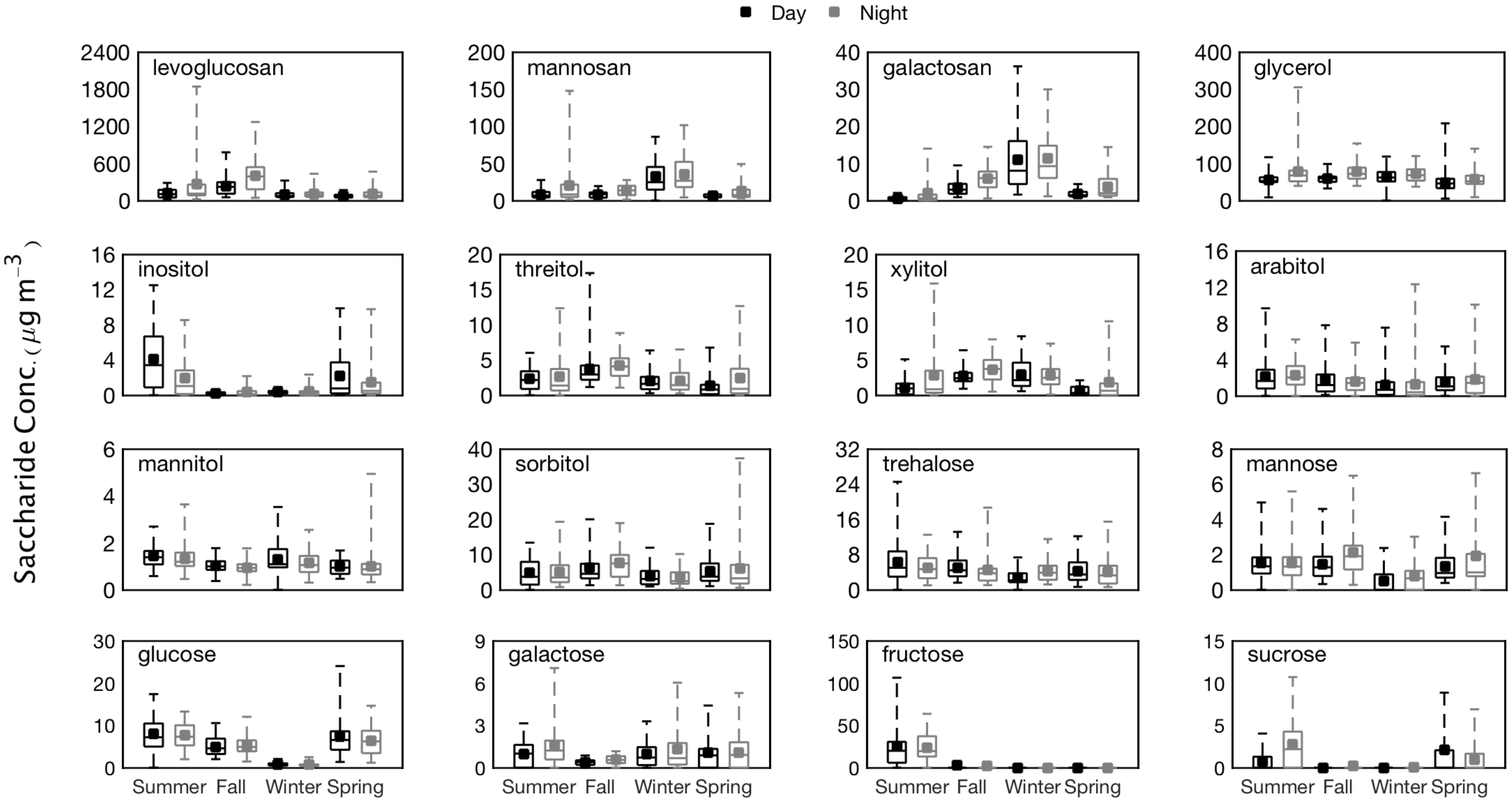
Carbonaceous component



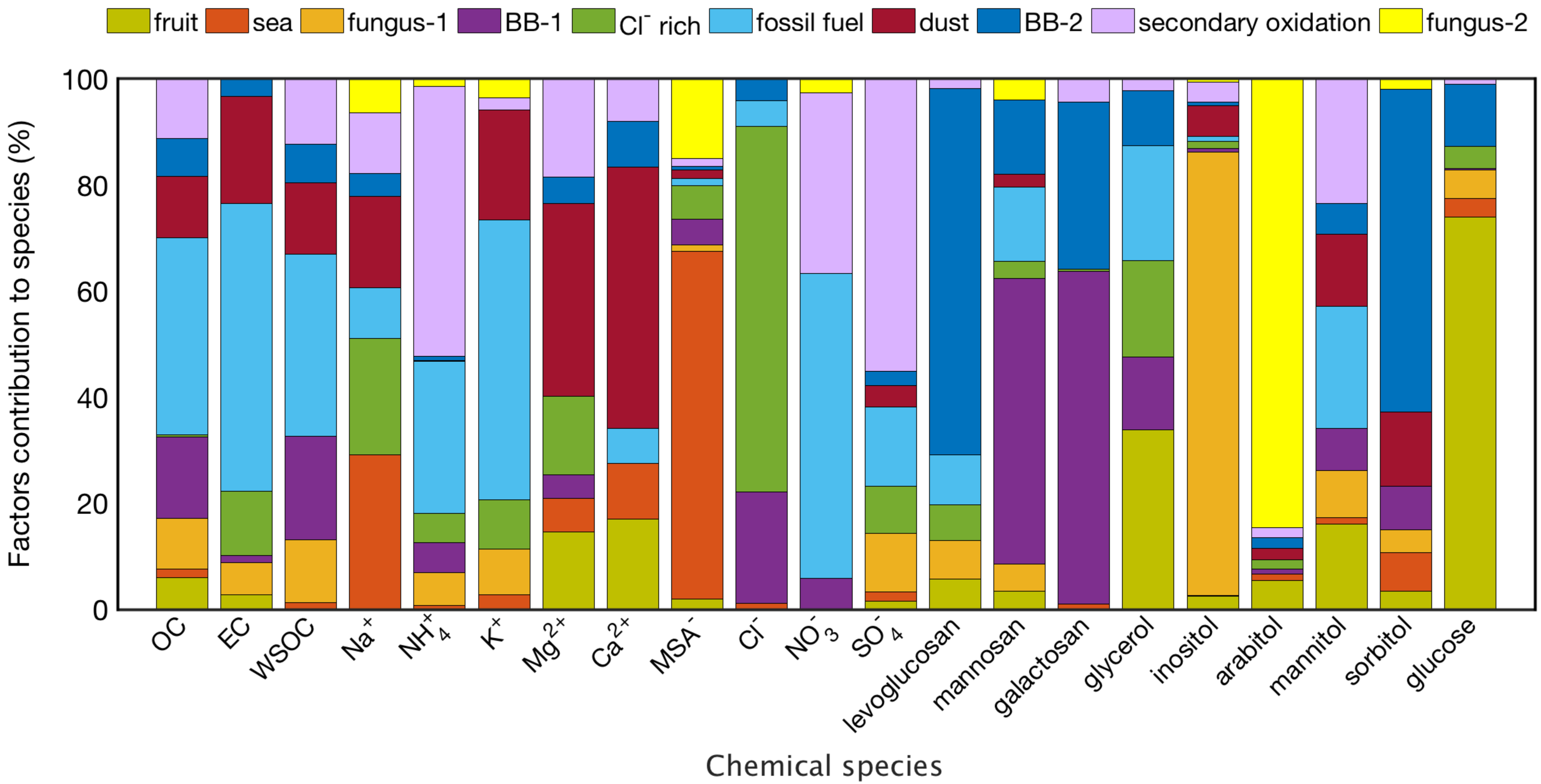
Ion component



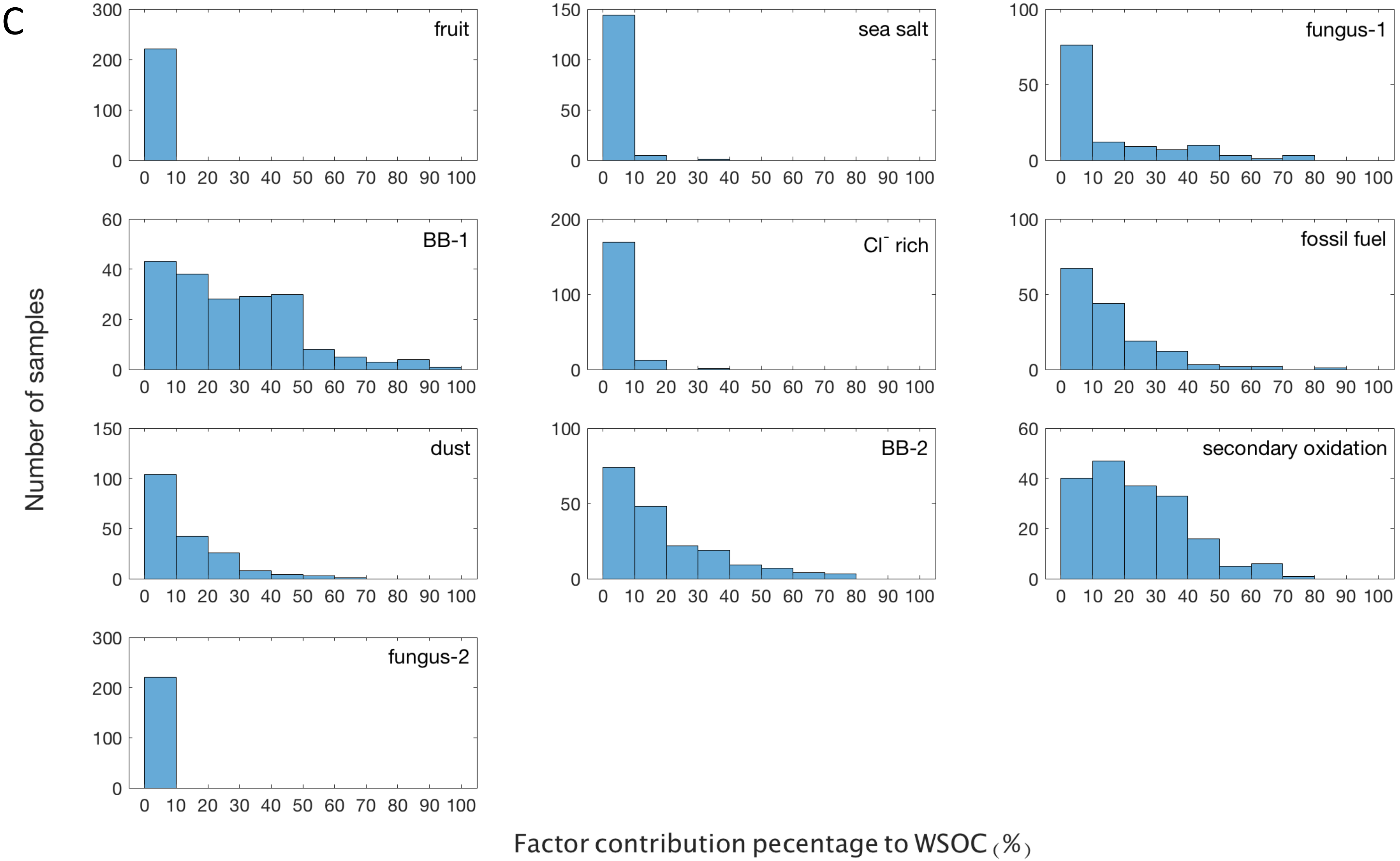
Saccharide component



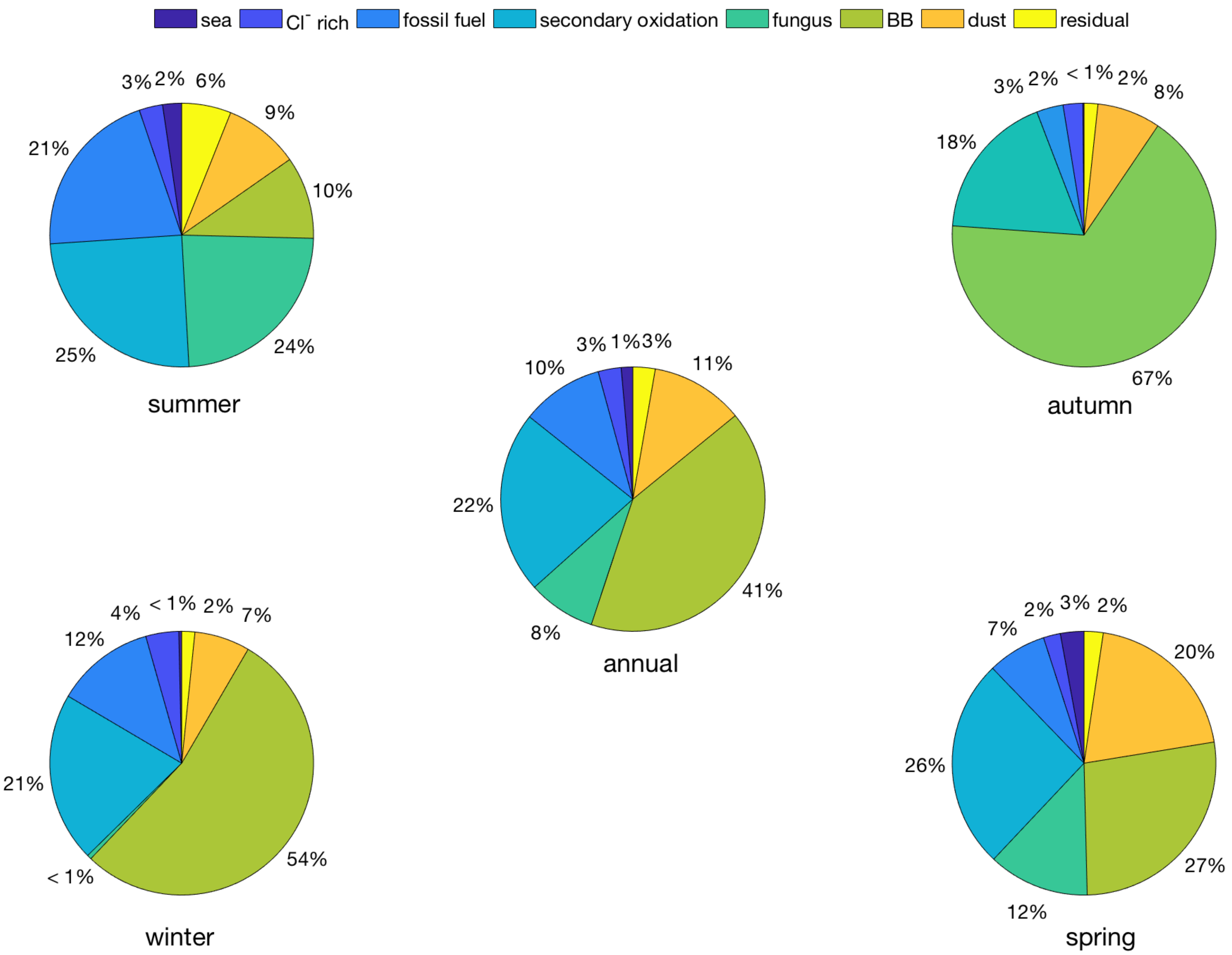
Source apportionment



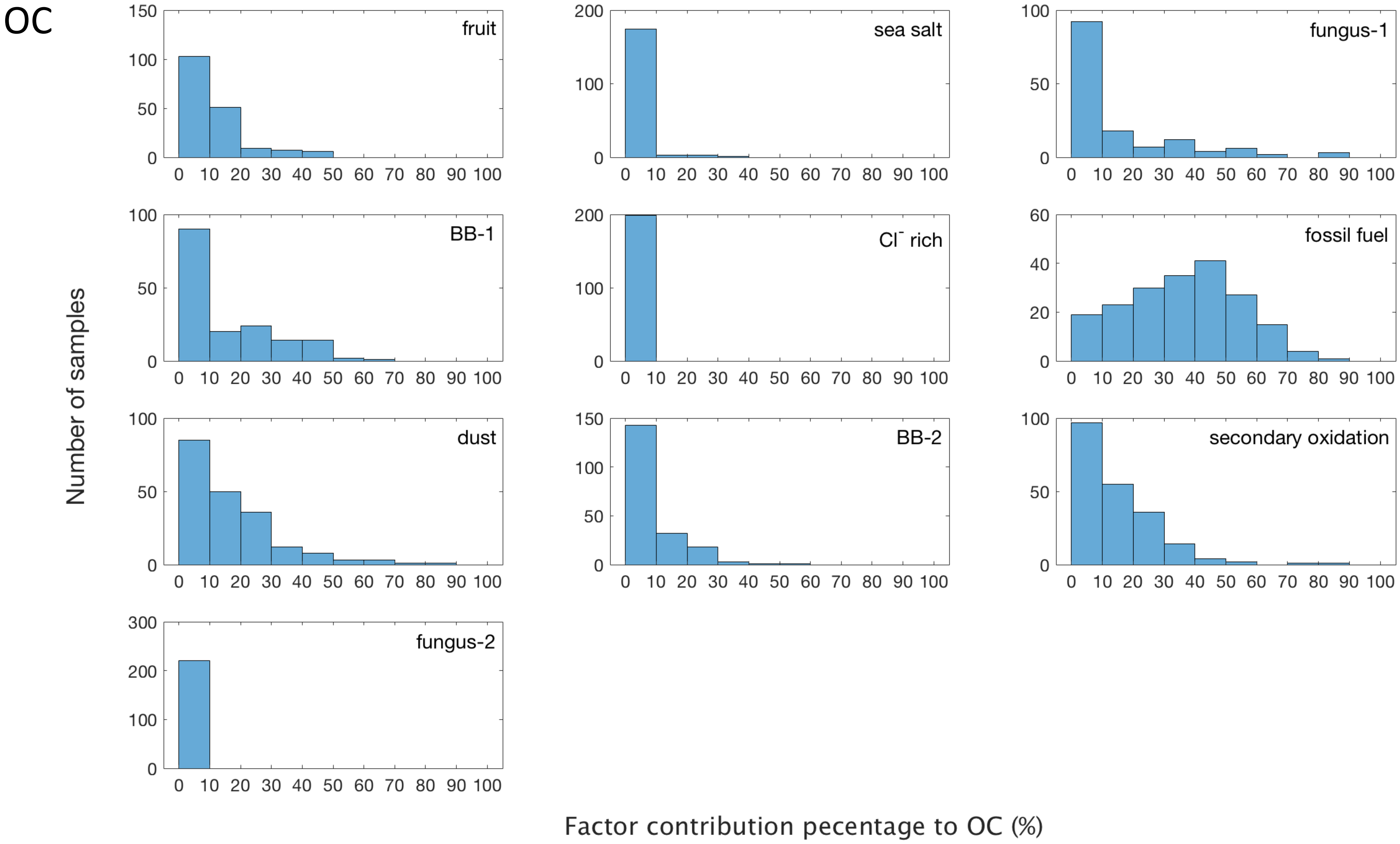
WSOC


fruit
sea salt
fungus-1
BB-1
Cl⁻ rich
fossil fuel
dust
BB-2
secondary oxidation
fungus-2
Number of samples
Factor contribution pecentage to WSOC (%)

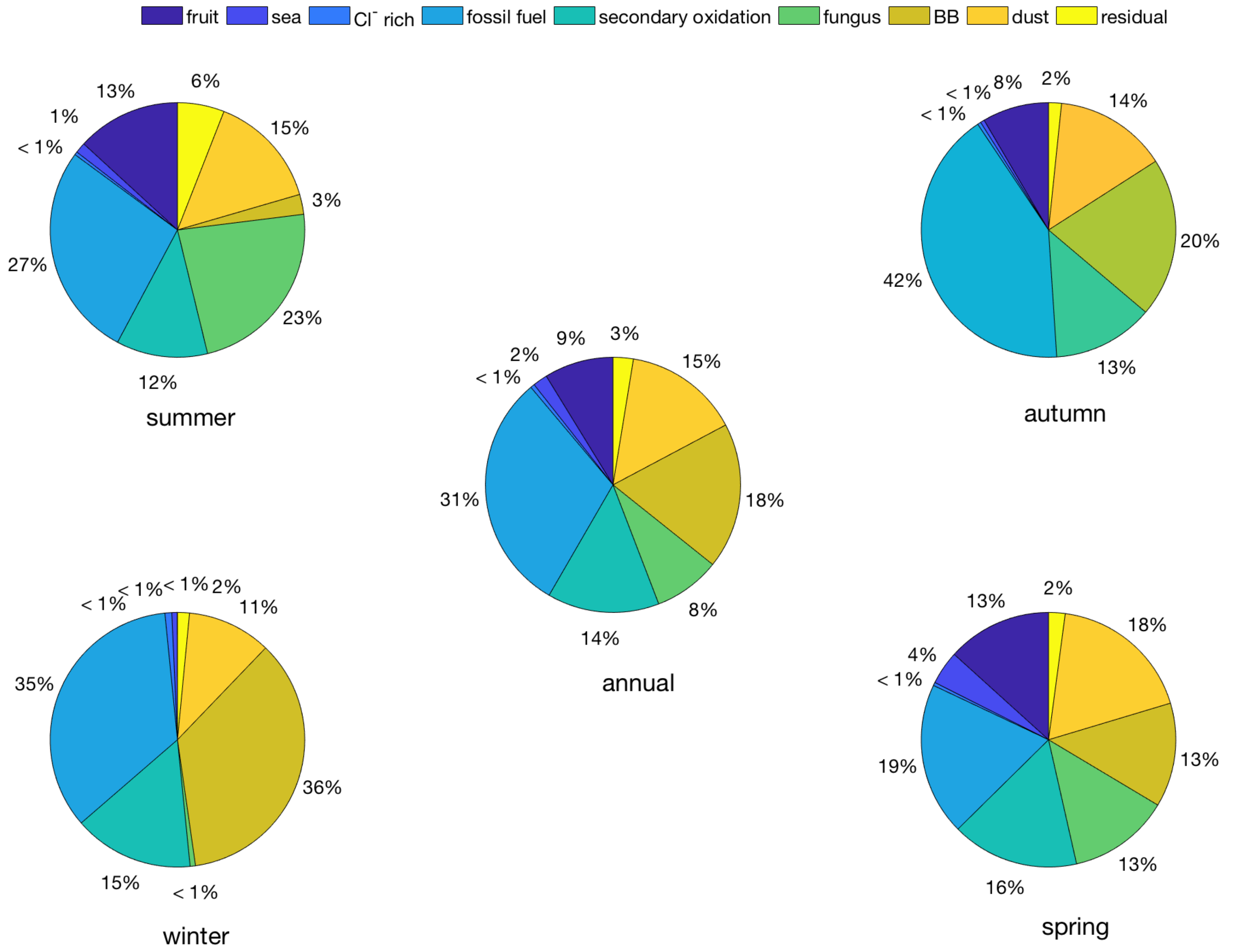
WSOC



sea
Cl⁻ rich
fossil fuel
secondary oxidation
fungus
BB
dust
residual
3%
2%
6%
9%
10%
21%
25%
24%
summer
3%
2%
< 1%
2%
8%
18%
67%
autumn
3%
1%
3%
10%
11%
22%
41%
8%
annual
4%
< 1%
2%
7%
12%
21%
< 1%
54%
winter
2%
3%
2%
7%
20%
26%
27%
12%
spring

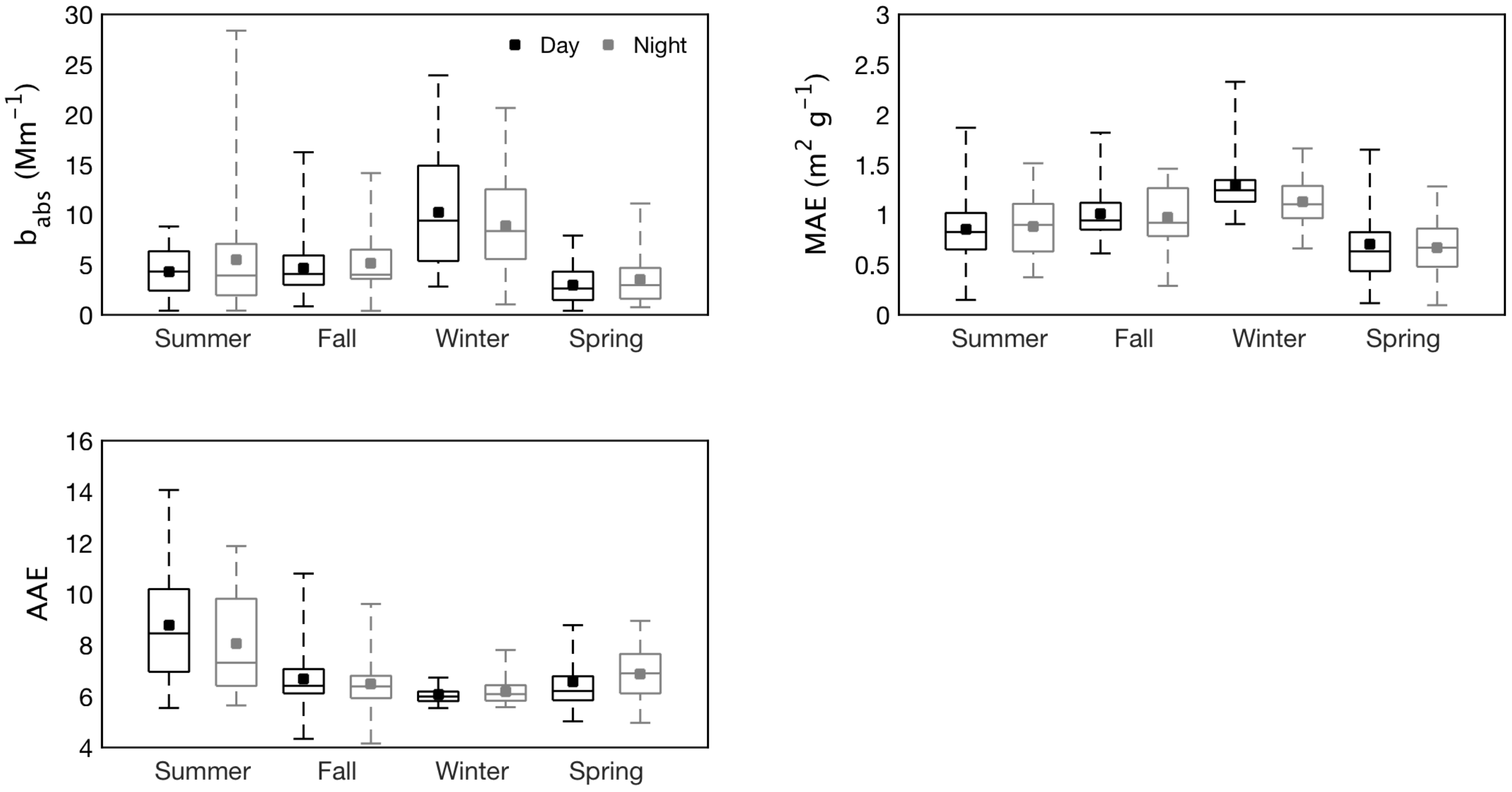

OC
Number of samples
fruit
sea salt
fungus-1
BB-1
Cl⁻ rich
fossil fuel
dust
BB-2
secondary oxidation
fungus-2
Factor contribution pecentage to OC (%)

OC



fruit
sea
Cl⁻ rich
fossil fuel
secondary oxidation
fungus
BB
dust
residual
13%
6%
1%
15%
< 1%
3%
27%
23%
12%
summer
< 1%
8%
2%
14%
< 1%
20%
42%
13%
autumn
9%
3%
2%
15%
< 1%
31%
18%
8%
14%
annual
< 1%
< 1%
< 1%
2%
11%
35%
36%
15%
< 1%
winter
13%
2%
18%
4%
< 1%
13%
19%
13%
16%
spring

Light-absorbing property



Absorption coefficient

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

- 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 (2mL)；
- Factor is used to estimate the absorption signal for the full filter, which is 50；
- 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 m^{-1}) is the absorption coefficient
- λ（310-470nm)

Mass Absorption Efficiency of BrC

$$\text{MAE of } BrC_{WSOC} = b_{abs}/WSOC$$

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

Source impact to light absorption

- Independents (7):

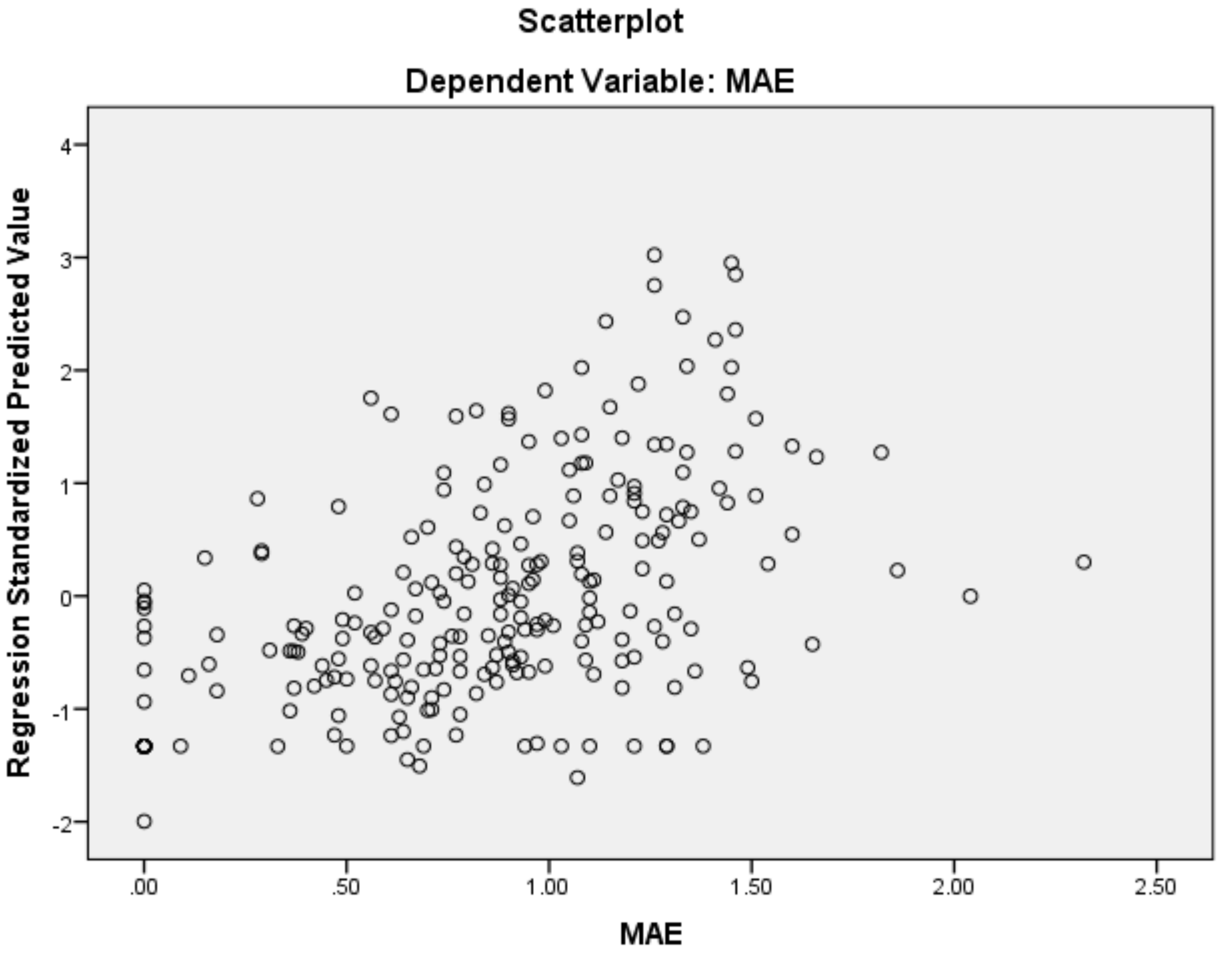
  Source contribution to WSOC (%)

- Dependent:

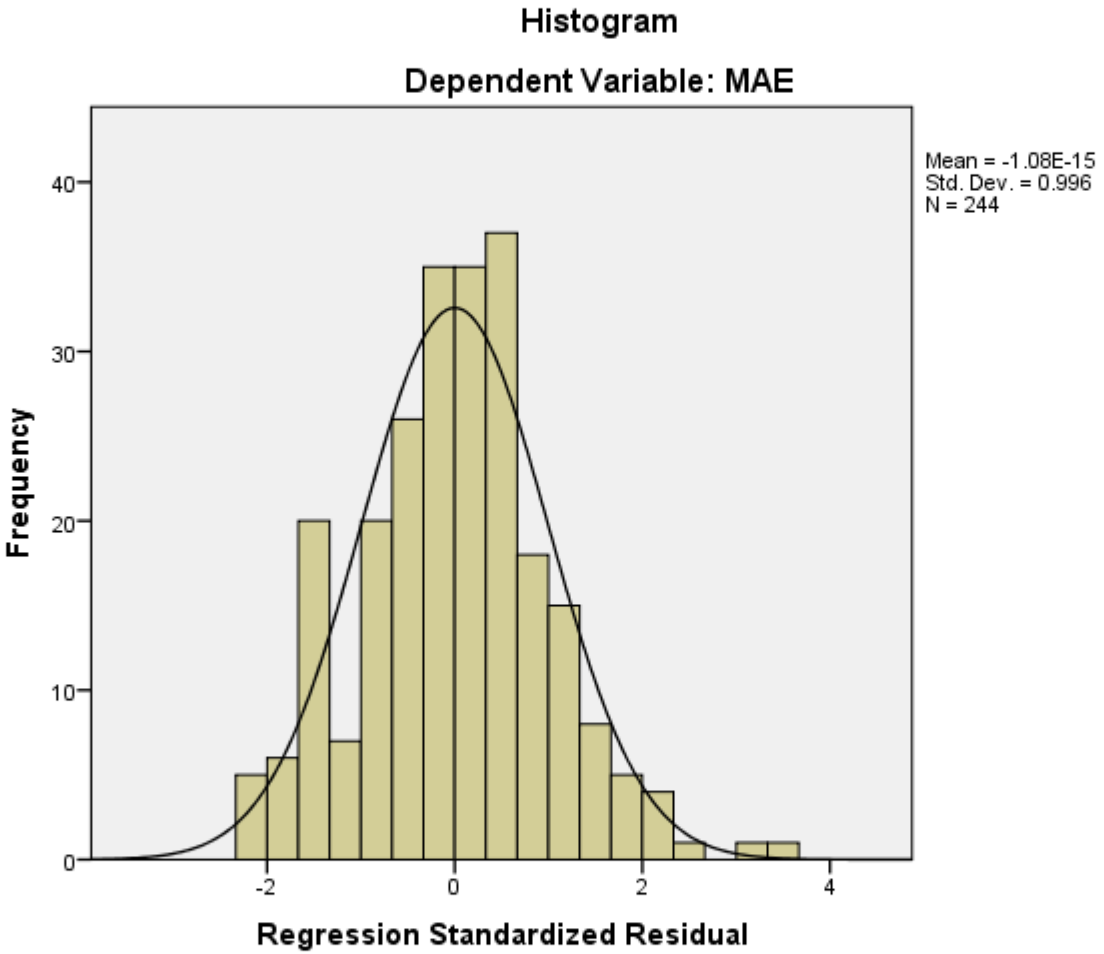
  MAE (M m^{-1})

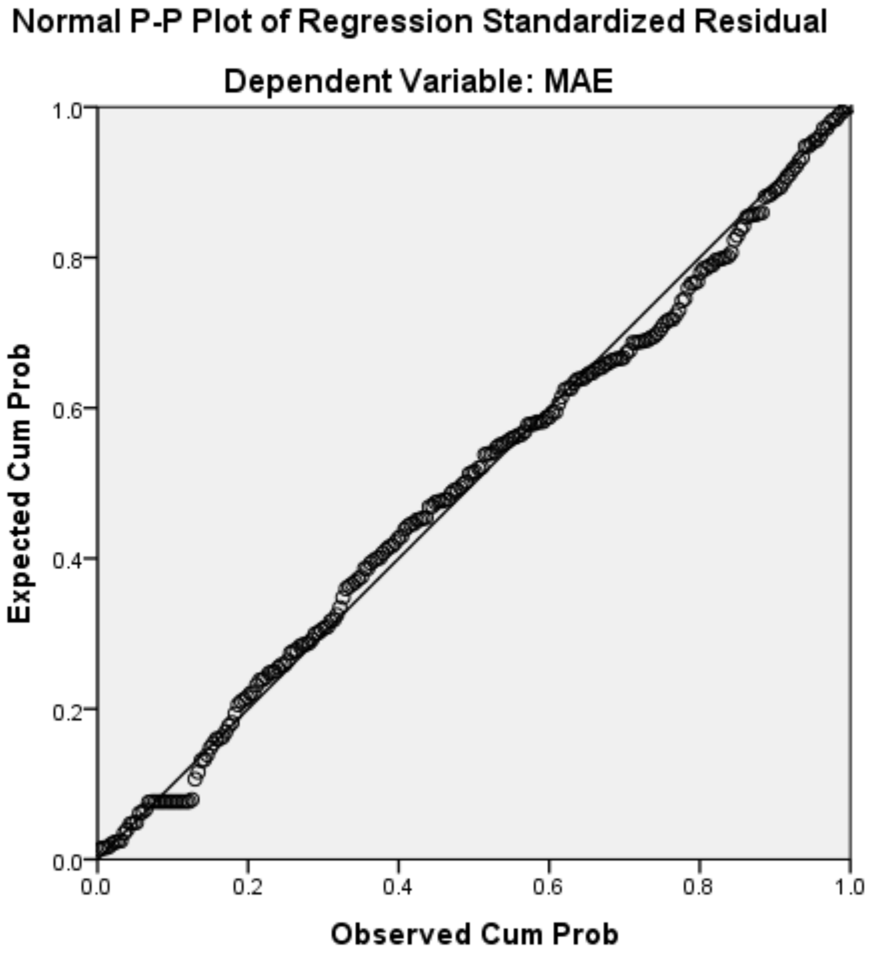
MAE=0.552+0.007*BB+0.006*fossil

R=0.5, P<0.05



Normal distribution of standardized residual





Conclusions

- 8 types of aerosol sources including biomass burning, fossil fuel combustion, secondary oxidation, dust, fungus, sea salt, fruit and Cl^- rich source were found in Nanjing whose performances had the different seasonal patterns.
- Biomass burning is the annual most important contributor to WSOC and fossil fuel combustion is the annual most important contributors to OC. Fruit source contributed to OC but not to WSOC. Fungus emission played a non-neglible role for both WSOC and OC.
- Biomass burning and fossil fuel combustion are two main factors influencing MAE of water-soluble BrC in $PM_{2.5}$ of Nanjing.

Next steps

- Analyze the meteorological condition to illustrate the seasonal variation of species levels and aerosol source contributions.
- Calculate the light absorption of carbonaceous species in different seasons.
- Further explore the connection between light absorbing property and pollution sources.

Thank you for your suggestions.