4th ACAM Workshop 2019

Case study of the effects of aerosol chemical composition and hygroscopicity on the scattering coefficient in summer, Xianghe, southeast of Beijing, China

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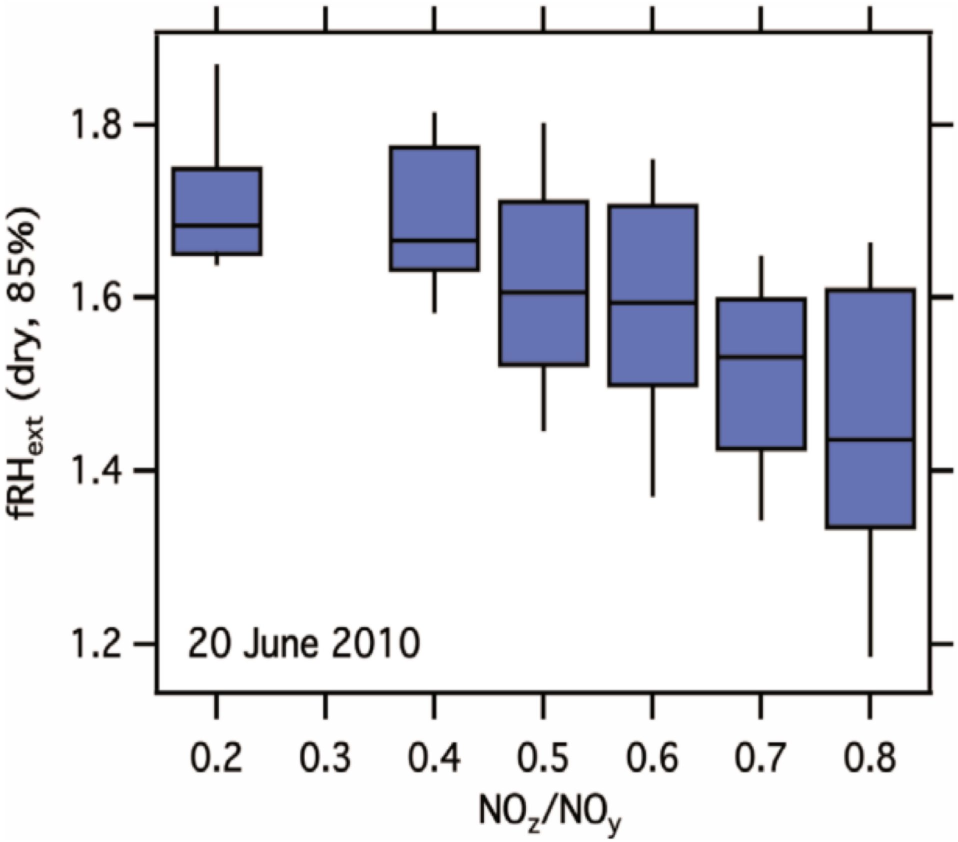
Content

Background 1：Effects of atmospheric composition



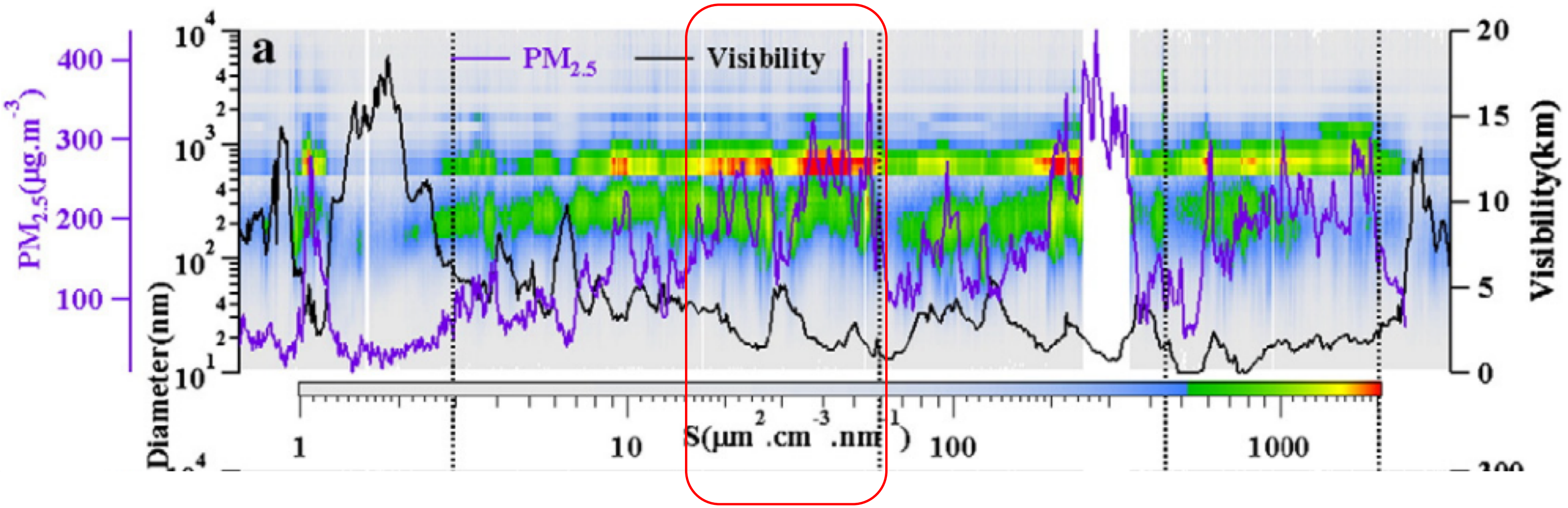
Studies have shown that the **chemical composition and concentration** of aerosols will directly and indirectly affect visibility.

Wang et al. found that the contribution of extinction components (such as **secondary nitrate and organic carbon**) to the optical extinction coefficient was much higher than their contribution to the $PM_{2.5}$ mass concentration.

For example, at 85% RH, the aerosol scattering coefficient increases by approximately **1.4-1.7 times**. With the increase of aerosol oxidation, the scattering growth factor gradually decreases (Langridge et al., JGR, 2012).

Background 2： Effects of spectral distribution

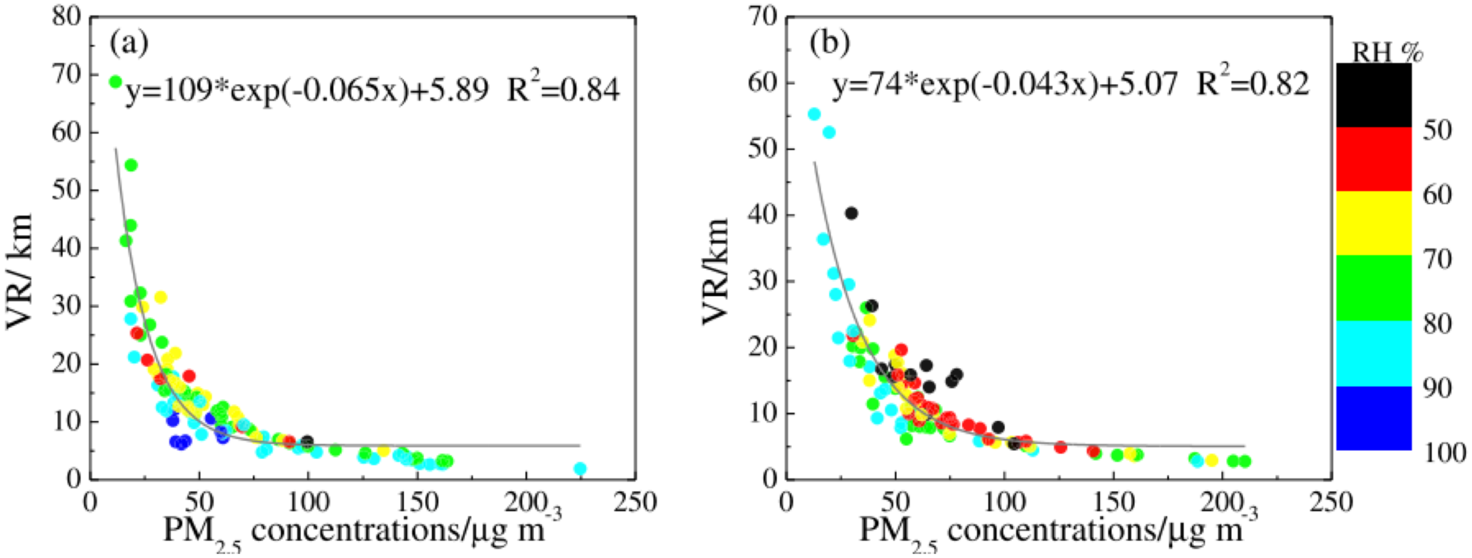
Studies have found that aerosol surface area concentrations and aerosol extinction caused by them exhibit uneven seasonal changes, with their highest values observed in **winter and summer**.



The correlation between aerosol surface area concentration and $PM_{2.5}$ was 0.90 and visibility was -0.75. Among them, the aerosols of 0.6-1.4 µm are the main extinction particles (Wang et al.. , STE 2014). Mie model can be used to calculate the change of aerosol extinction coefficient with **particle number, particle size distribution and chemical composition**.

Background 3： Effects of relative humidity

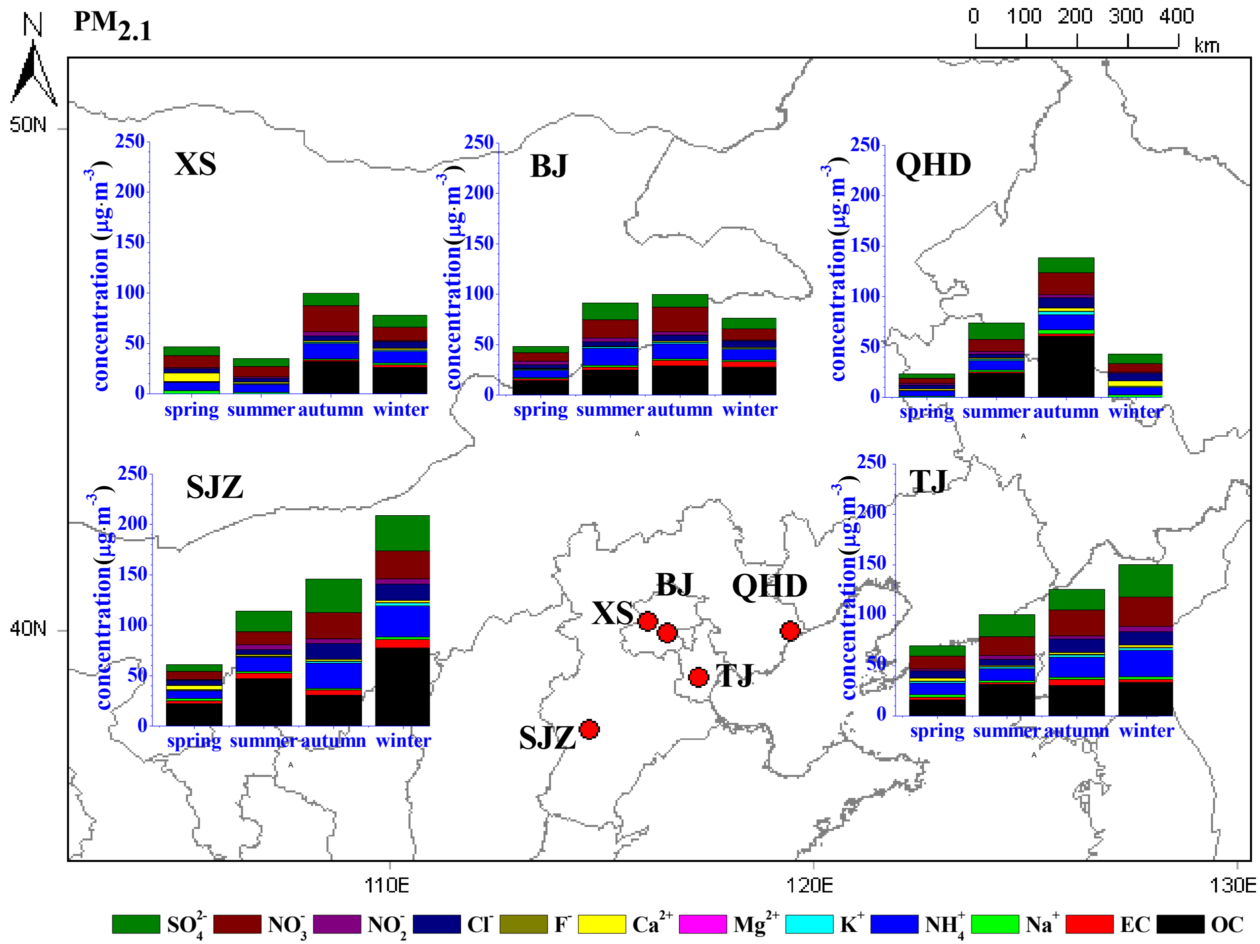
Deng et al. indicate that high relative humidity weather associated with precipitation will increase **hygroscopicity**. The increase in fine particles in high relative humidity environments has a greater impact on visibility.



In an environment with low wind speed and high humidity, high concentrations of $PM_{2.5}$ often cause **a sharp decline in visibility** (Wang et al., STE, 2017).

The interaction between water vapor and aerosols plays a key role in determining aerosol properties and has a great influence on air quality (Wu et al.,2018).

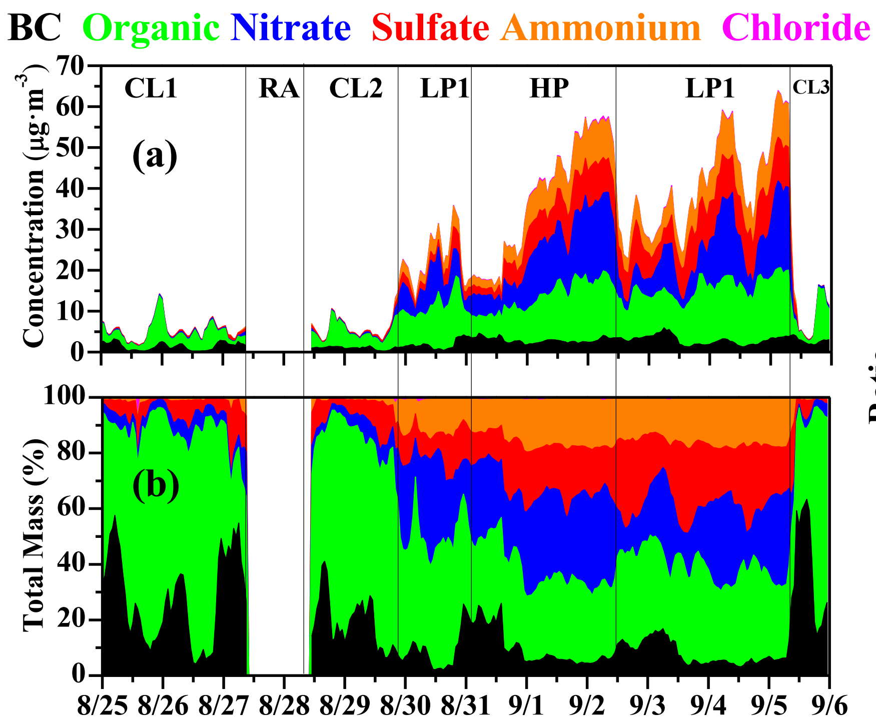
Aerosol chemical composition in North China

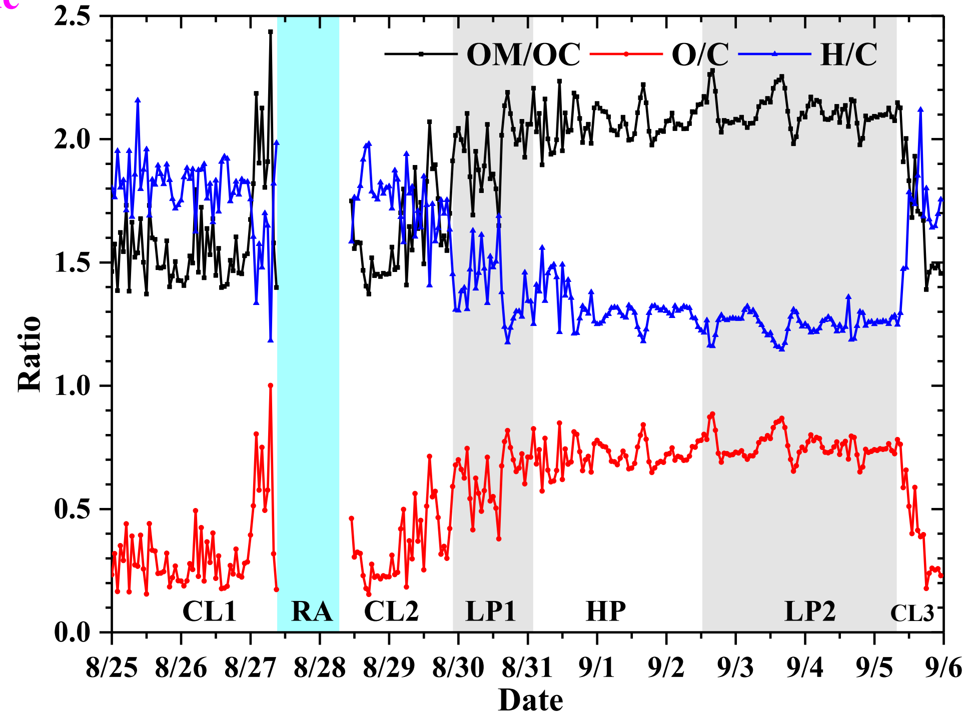


Water soluble ions and Carbonaceous aerosols in $PM_{2.1}$ in 2014 four Seasons in Beijing, Xiangshan, Tianjin, Qinhuangdao and Shijiazhuang

Zou et al., AR, 2017

Aerosol chemical composition in Summer Beijing





Annual change in aerosol chemical composition concentration and percentage, elemental ratio, Beijing, 2017 (CL is a clean period, RA is a precipitation period, LP is a lighter pollution, HP is a heavier pollution)

Zou et al., AE, 2019

2. Experiments

High-resolution time-of-flight aerosol mass spectrometer

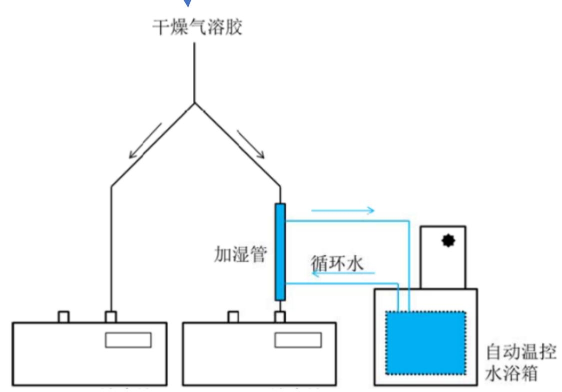
Organic
sulfate
Nitrate
Ammonium
Chlorine

Single particle aerosol mass spectrometer (SPAMS)

Black carbon

Aerosol

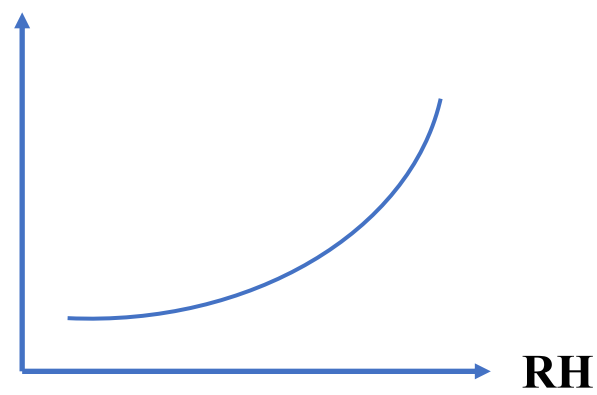
Number spectrometer (SMPS, WPS)



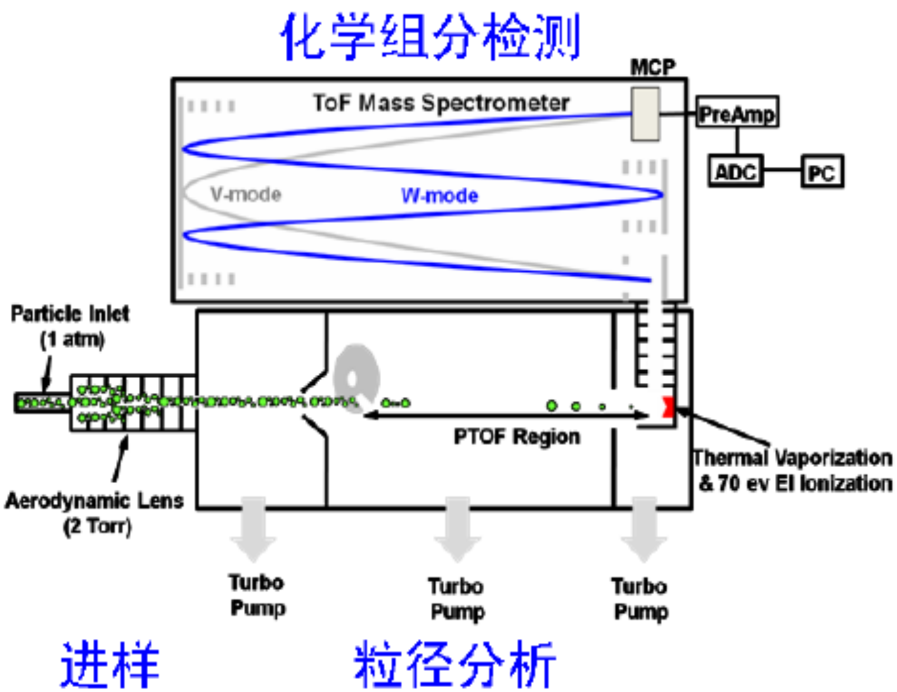
Unattended multifunctional hygroscopicity system

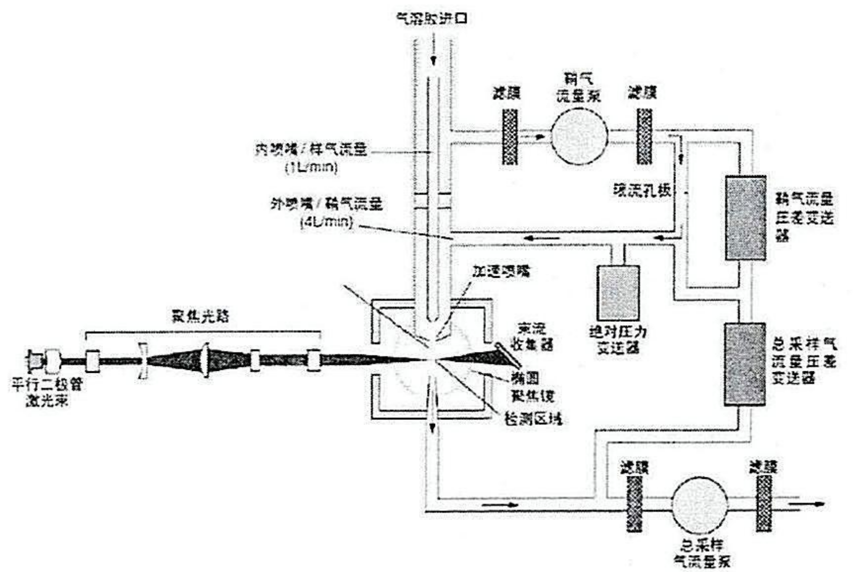
light scattering enhancement factor f(RH)

$$f(RH)=\sigma_{RH} / \sigma_{dry}$$



Aerosol mass spectrometer





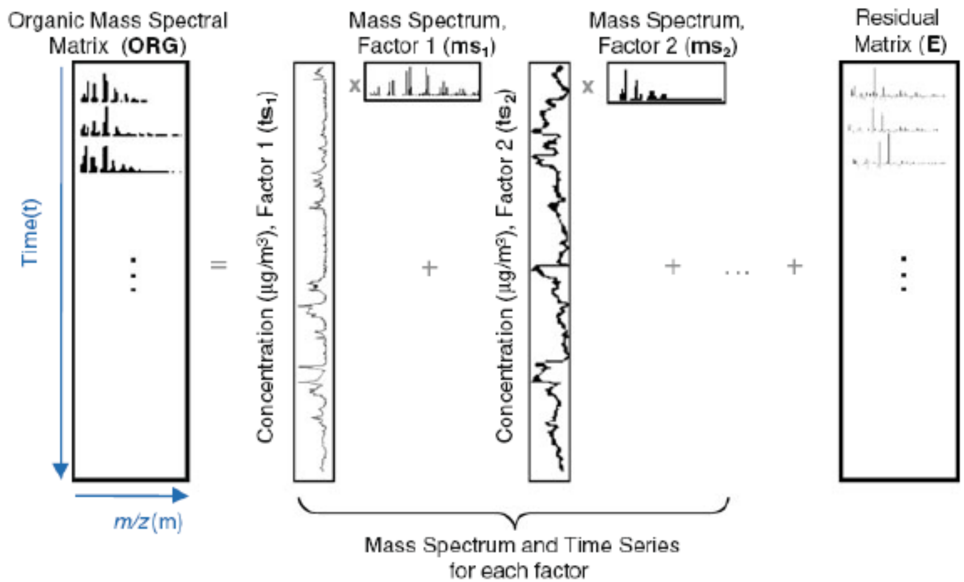
High-resolution time-of-flight aerosol mass spectrometer (HRAMS)

Single particle aerosol mass spectrometer (SPAMS)

Data processing methods

HRAMS：

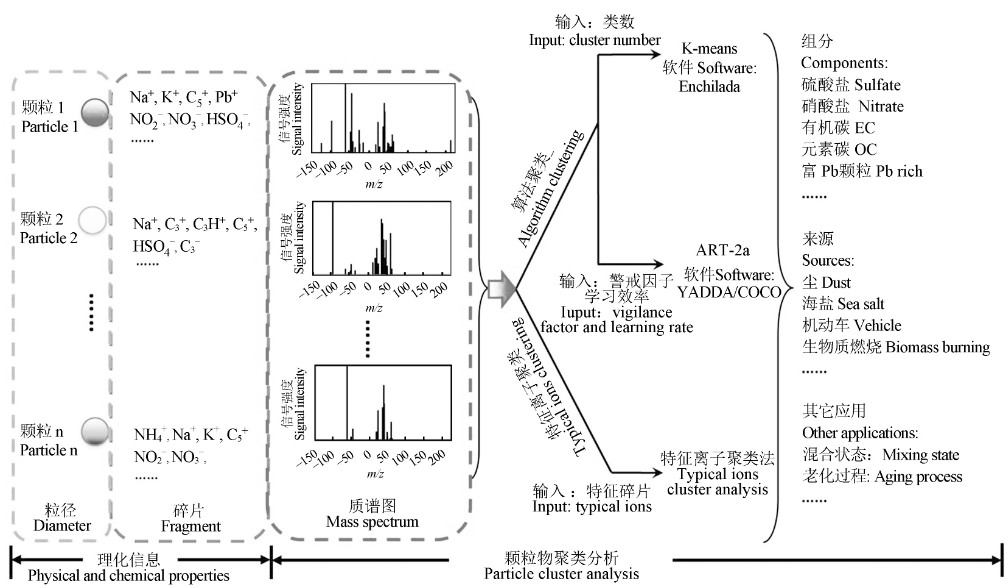
positive matrix factorization (PMF)



SPAMS:

Adaptive Resonance Theory neural network,

ART-2a



Mie Model

Mie Model：

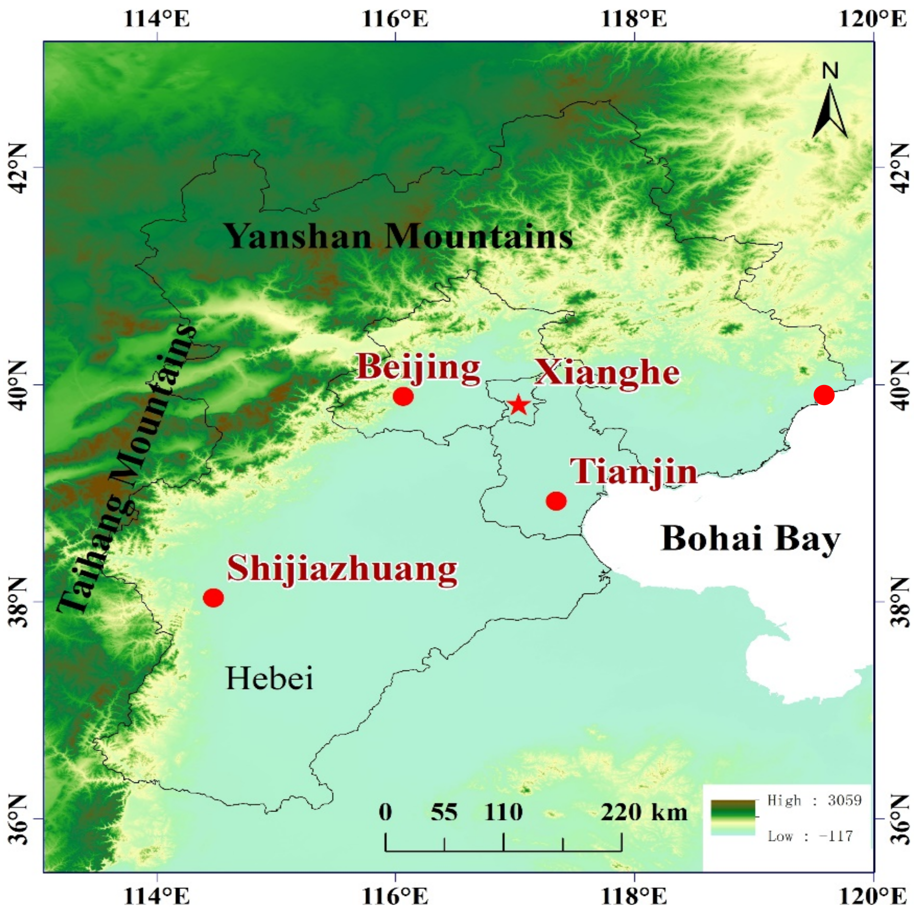
$$Ext_{Mie(dry)} = \int Q_{ext} \times \pi \times r^2 \times N(r)\, dr$$

Influence factors ：

1. Chemical composition :$m \rightarrow Q_{ext}$
2. Number concentration spectrum ：$N(r)$
3. Relative humidity ：r, $r \rightarrow Q_{ext} + N(r)$

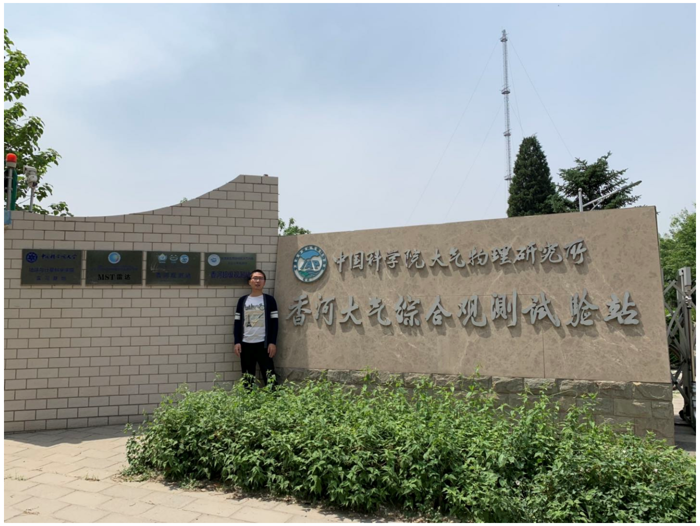
Visibility = k / Ext × 1000

Sampling site

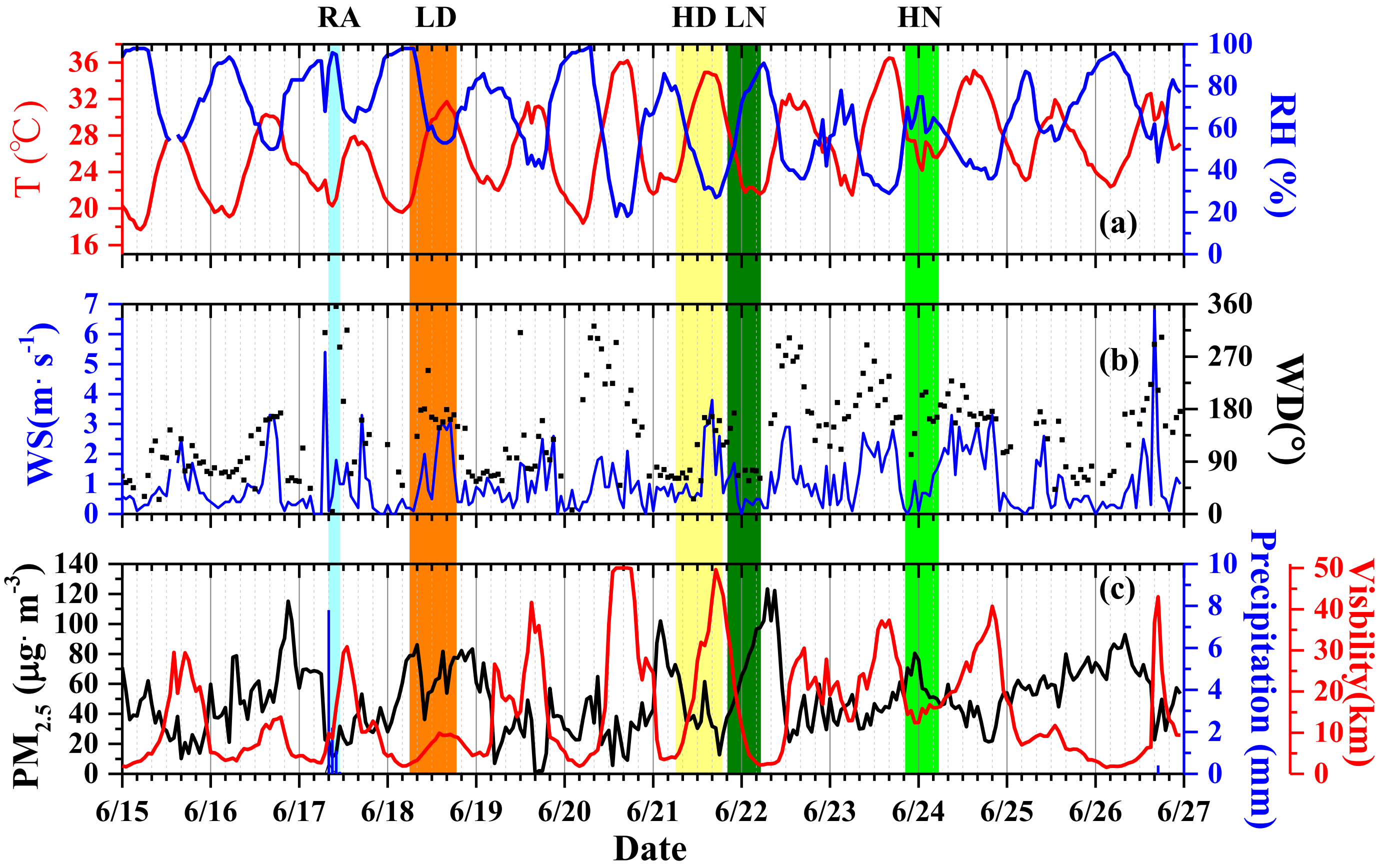


The measured station, which is located in the Xianghe atmospheric observation station (E116.95°, N39.76°), Institute of Atmospheric Physics, Chinese Academy of Sciences. The county town is about 3 km away from observation station, which surrounded by the countryside.

The topography of Northern China Plain. The location of the observation site is marked with a dot.



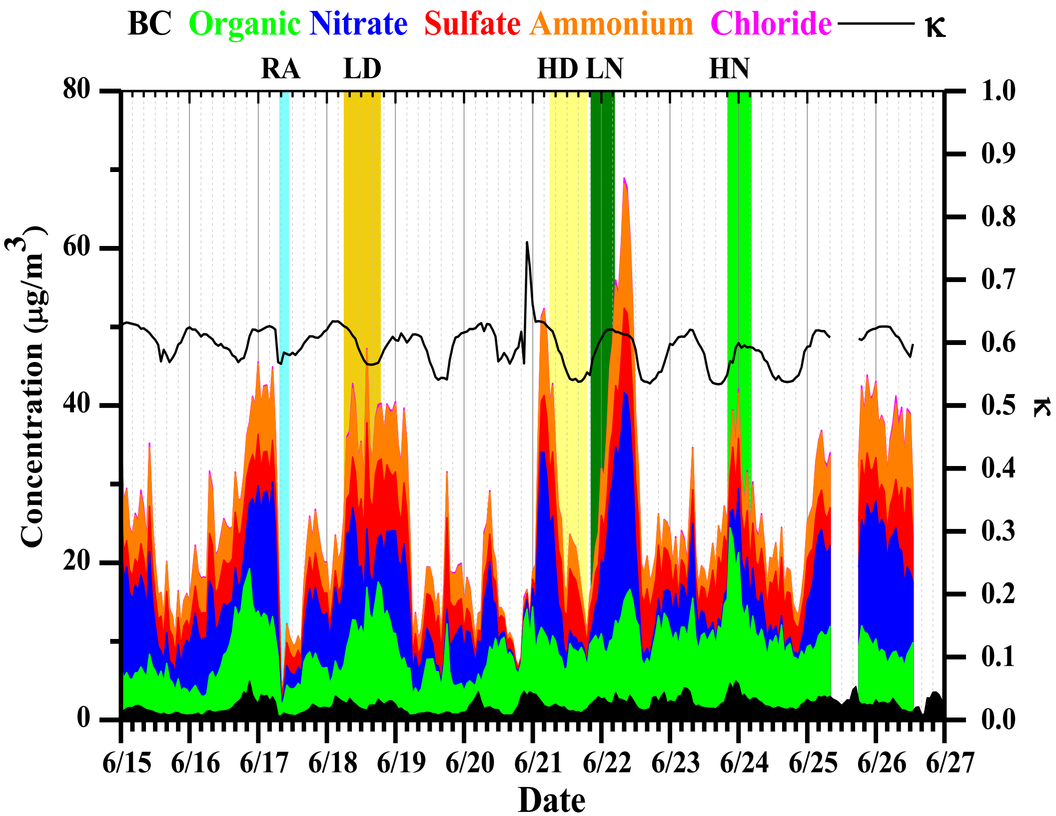
3. Results and discussion

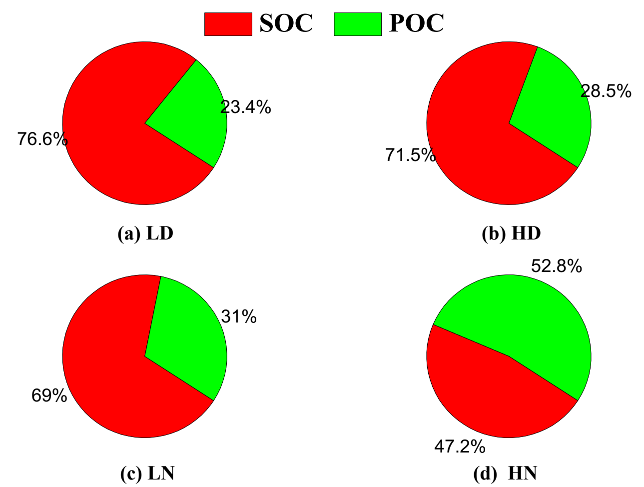


RA is a precipitation period, **LD** is a low visibility period in the day, **HD** is a high visibility period in the day. **LN** is the period of low visibility at night, **HN** is the period of high visibility at night.

Time series of (a) ambient temperature and relative humidity; (b) wind speed and wind direction; (c) $PM_{2.5}$, precipitation and visibility.

Chemical components in Xianghe



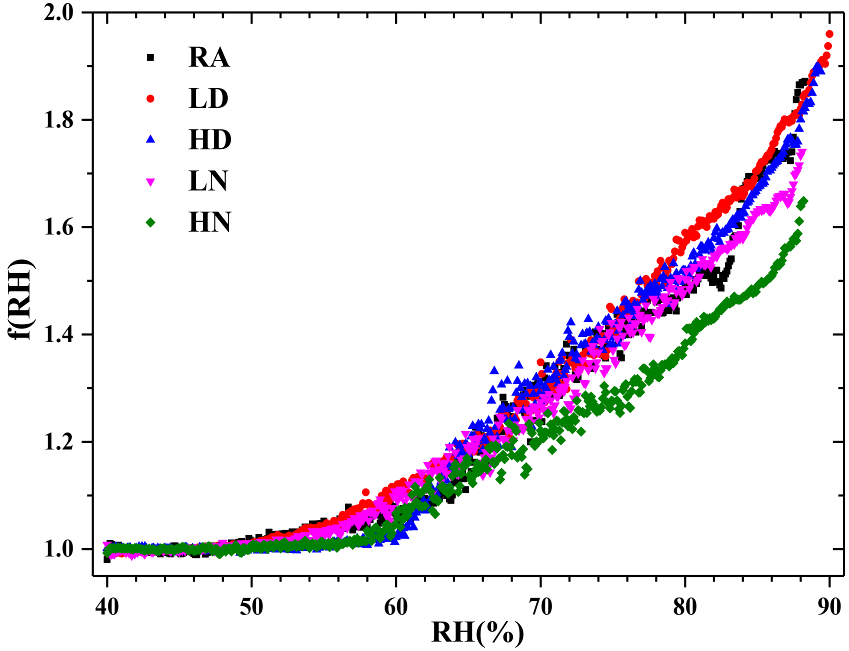


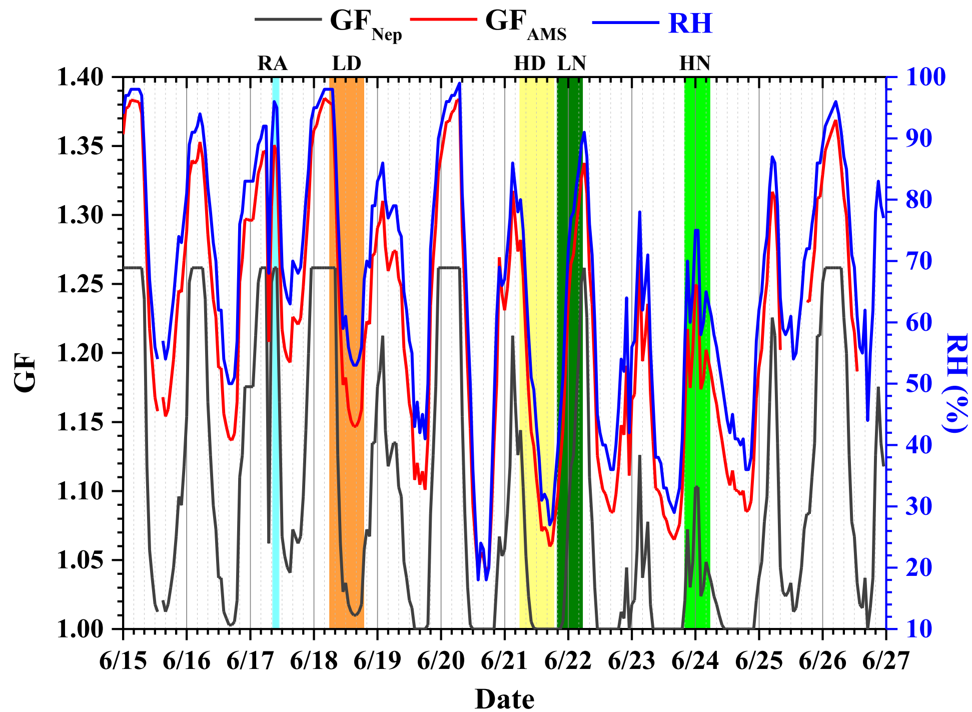
The mass percentages of secondary organic aerosol (SOA) and primary organic aerosol (POA) to organic aerosol were 76.6% and 23.4%, respectively, during LD.

The mass percentages of a secondary inorganic aerosol (nitrate, sulfate and ammonium) measured were 64.5% and 68.3% during LD and LN, which were higher than those (63.6% and 46.1%) observed during HD and HN, respectively.

The hygroscopic parameters κ were 0.59 and 0.60 during LD and LN, which were slightly higher than those (0.57 and 0.58) observed during HD and HN, respectively, indicating that the variation of aerosol chemical composition had a limited impact on hygroscopicity. ***Zou et al., AR, 2019***

Aerosol hygroscopicity in Xianghe



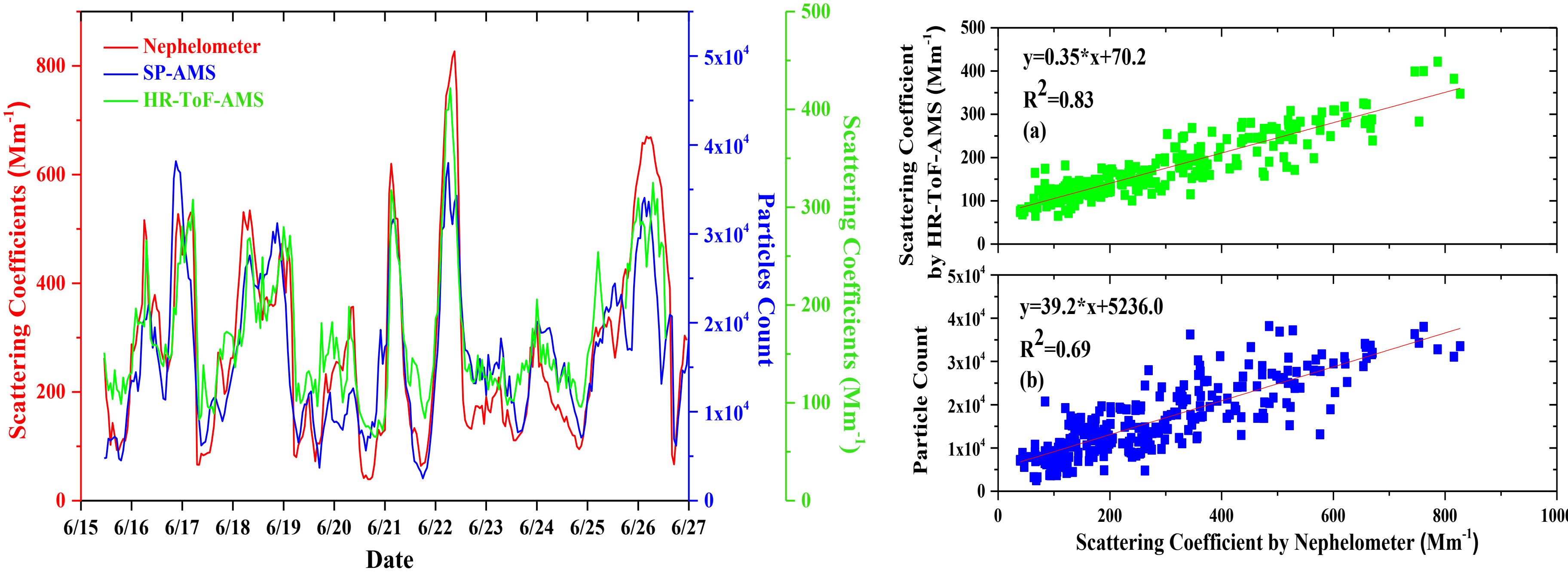


The values of DRH in LD and LN are about 51.0% and 52.0%, which are lower than that in HN and HD, respectively, about 58.0% and 60.0%. This indicates that in low visibility days, aerosols are easier to deliquescence, which results in an increase in scattering coefficient.

The f (RH) of low visibility days is almost greater than that of high visibility events, day or night.

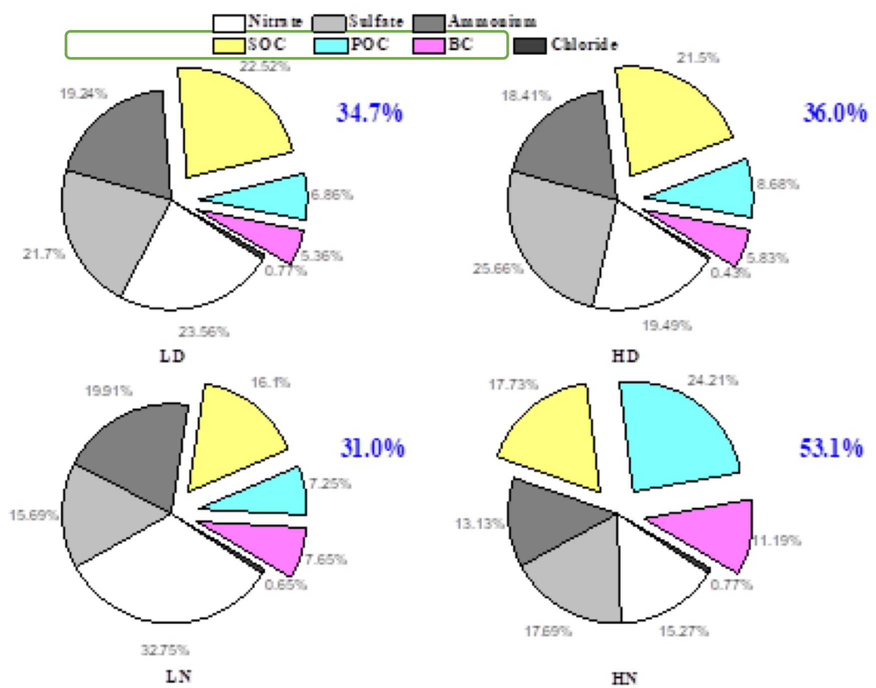
Growth factor was derived from the wet and dry nephelometer.

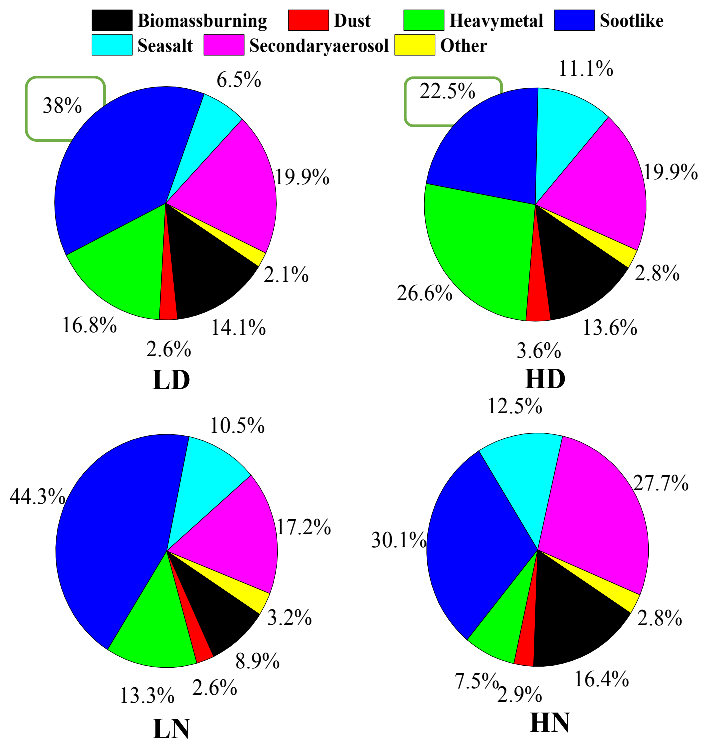
Comparison of scattering characteristics calculated by different models



The scattering coefficient calculated by the mass concentration of aerosol chemical composition measured by HR-ToF-AMS is closer to the actual value of the scattering coefficient than that fitted by the concentration measured by SP-AMS.

Source Analysis



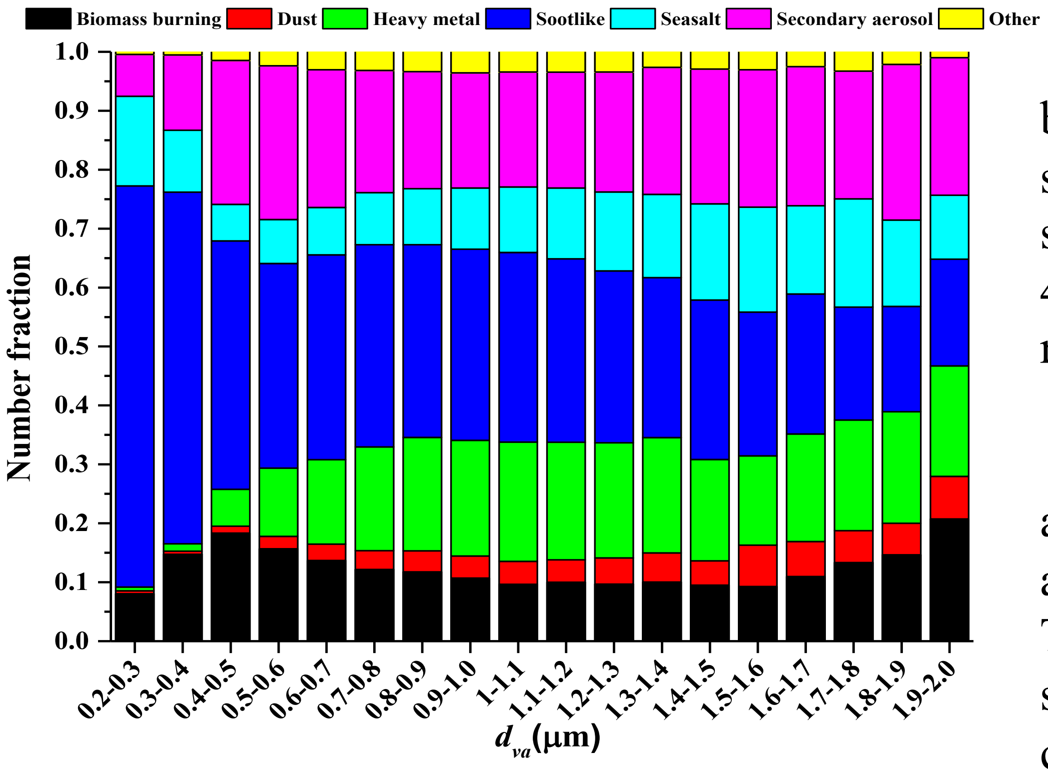


Source Contribution of Aerosol Mass Concentration and Quantity Concentration in Different Periods of Xianghe Summer Case in 2018

The contribution of mass concentration of seven components to aerosol in different events.

The contribution of number concentration of seven sources to aerosol in different events.

Source Contribution of Aerosol Number Concentration

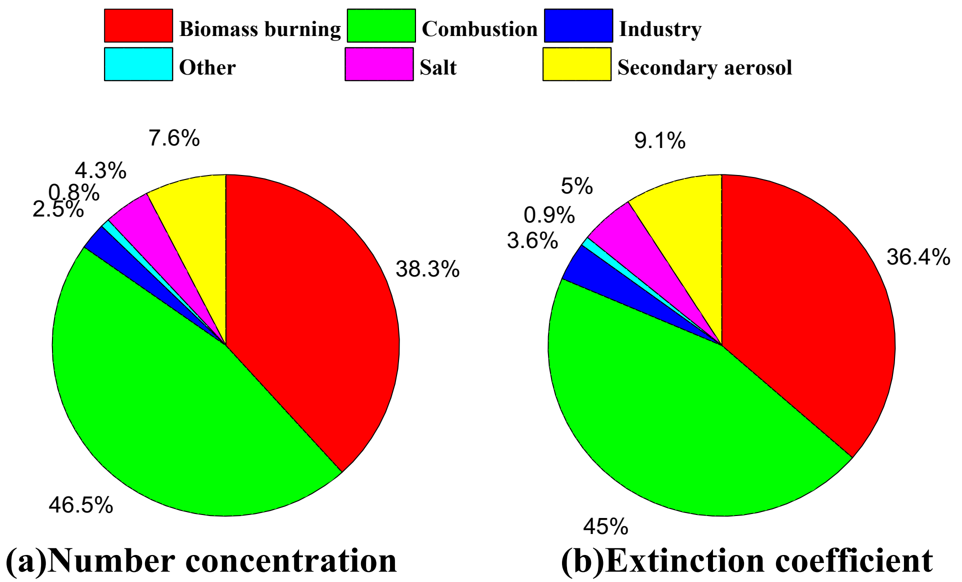


Size-resolved number fraction of the aerosol number concentration sources during this observation.

The average number fractions of biomass combustion source, industrial source, combustion source and secondary aerosol are 13.1%, 11.3%, 42.4% and 19.2% respectively, ranging from 0.2 to 1.0 um.

The number fraction of secondary aerosol sources is stable between 0.4 and 2.0 um, with an average of 22.2%. The combustion source aerosols and secondary aerosols mainly concentrate on the submicron, which is also the main particle size which affects the extinction effect.

Contribution of Number Concentration Sources to Extinction



Using Mie scattering model, the refractive index of combustion source is assumed to be 1.8-0.54i, the refractive index of biomass combustion source is 1.53-0.54i, and the other sources are assumed to be 1.53-0i.

The proportion of (a) concentration and (b) extinction coefficient of aerosols from different sources in the winter case of Xianghe in 2018

The extinction contribution ratios of combustion source and biomass combustion source were 45.0% and 36.4% respectively, which were reduced by 3.2% and 4.9% compared with the quantity concentration ratios (46.5% and 38.3%) of the sources, which was related to the more optical absorption components in the components of their sources.

4. Conclusions

- The variation of **aerosol chemical composition** had a limited impact on visibility.

- The scattering coefficient recalculated by mass concentration of aerosol chemical composition is **closer** to the real value of scattering coefficient than that fitted by number concentration.

- Aerosol is **more easily deliquescent** in low visibility events than that in high visibility events, resulting in an more easily increase in scattering coefficient in low visibility events.

- The f(RH) during low visibility events were almost greater than those during high visibility events.

- RH is the main reason affecting the hygroscopic growth of aerosol, resulting in the decrease of visibility.

Thank you for your attention!

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Jianan Zou. Case study of the effects of aerosol chemical composition and hygroscopicity on the scattering coefficient in summer, Xianghe, southeast of Beijing, China, Atmospheric Research,2019,225:81-87,