The Chemical Composition Characteristics of Aerosol and its Impact on the Visibility in North China Plain

Jianan Zou[1,2], Zirui Liu[2], Bo Hu[2], Yuesi Wang[1,2]

1.College of Atmospheric Sciences, Key Laboratory of Arid Climatic Change and Reducing Disaster of Gansu Province, Lanzhou University, Lanzhou 730000, China;

2.State Key Laboratory of Atmospheric Boundary Layer Physics and Atmospheric Chemistry (LAPC), Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China;

Highlights

- Visibility and mass concentrations of $PM_{2.1}$ present non-linearity correlations in different RH.
- Organic matter, NH_4NO_3, $(NH_4)_2SO_4$ were the three main light extinction coefficients in Beijing.
- The increase concentration of NH_4NO_3, $(NH_4)_2SO_4$ and organic matter result in the occurrence of low visibility events in autumn or winter in NCP.
- As PMF model, 37.1% and 26.5% of the LEC came from secondary aerosol on PD in Beijing and Tianjin.

Abstract

To better understand the chemical composition (water soluble ions (WSIs) and carbonaceous aerosol (CA)) characteristics of aerosol and its impact on the visibility in North China Plain (NCP), four experimental sampling campaigns were carried out during Jun, 2013 to May, 2014. The sampling sites were located in Beijing, Xiangshan, Tianjin, Shijiazhuang, Qinhuangdao. The air pollution episodes mainly happened in autumn and winter in NCP. In the sight of different particle size distribution, the ratio of anions to cations in the fine size (0.64) was greater than that in the coarse size (0.54) in NCP. The coefficient of divergences indicates that the aerosol pollution had a similar characteristic in the five cities of NCP and pollutants had a characteristic of mutual influence and regional transfer process. There were different non-linearity correlations between visibility and mass concentrations in different relative humidity. When RH was greater than 70%, the visibility was less than 5km, showing that due to its hygroscopic growth in a higher RH, the increasing of $PM_{2.1}$ resulted in the decreasing of visibility. The Interagency Monitoring of Protected Visual Environments (IMPROVE) method was used to estimate the light extinction coefficients (LEC) from the measured concentrations of chemical species. Organic matter(OM), ammonium nitrate(NH_4NO_3), ammonium sulfate($(NH_4)_2SO_4$) were the three dominant species contributing to LEC in Beijing and had the highest proportion of total contributions to LEC in summer, accounting for 32.2%, 25.9%, 24.4%, respectively. The LEC of sea salts had not changed much in the full year, accounting for 4.1~5.3%(in Beijing) and 4.8~7.4%(in Tianjin). According to the Ambient Air Quality Standard, the days were divided into Pollutional Days (PD) and Attained Days (AD). The increasing concentrations of NH_4NO_3, $(NH_4)_2SO_4$ and OM resulted in an increase of LEC in NCP, which led to the occurrences of low visibility events in autumn and winter. NH_4^+, NO_3^- and SO_4^{2-} mainly existed in the fine size (diameter<2.1μm) in Beijing (73.5, 80.7, 78.0% on PD and 63.3, 79.4, 72.5% on AD) and Tianjin (81.0, 80.6, 82.1% on PD and 71.5, 44.3, 69.7% on AD). However, the CA, mainly coming from fuel combustion, also played an important part in the visibility impairment in the coarse size (2.1<diameter<9.0μm). According to positive matrix factorization (PMF) model, 37.1% of the LEC came from secondary aerosol on PD in Beijing and 26.5% in Tianjin. In addition, biomass burning, fuel combustion and fugitive dust were also important contribution sources of LEC in NCP.

Methodology

The sampling sites were located in Beijing(BJ), Xiangshan(XS), Tianjin(TJ), Shijiazhuang(SJZ), Qinhuangdao(QHD) in the North China Plain during Jun, 2013 to May, 2014.

A nine-stage sampler (Andersen Series 20-800, USA) was used to collect particles. Water soluble ions and carbonaceous aerosols were measured by ion chromatograph (DIONEX, ICS-90, USA) and thermal/optical carbon aerosol analyzer (DRI Model 2001A, Desert Research Institute, USA).

Results and discussion

As shown in Fig.1, in $PM_{2.1}$, the concentrations of WSIs and CA had a high value in summer and autumn in BJ(91.4, 99.7μg·m^{-3}), and it had a high value in winter in TJ(150.4μg·m^{-3}) and SJZ(208.8μg·m^{-3}) and a high value in autumn in QHD(138.6μg·m^{-3}). The similar change between $PM_{2.1}$ and PM_9 illustrates the regional and synchronal characteristic of air pollution in NCP.

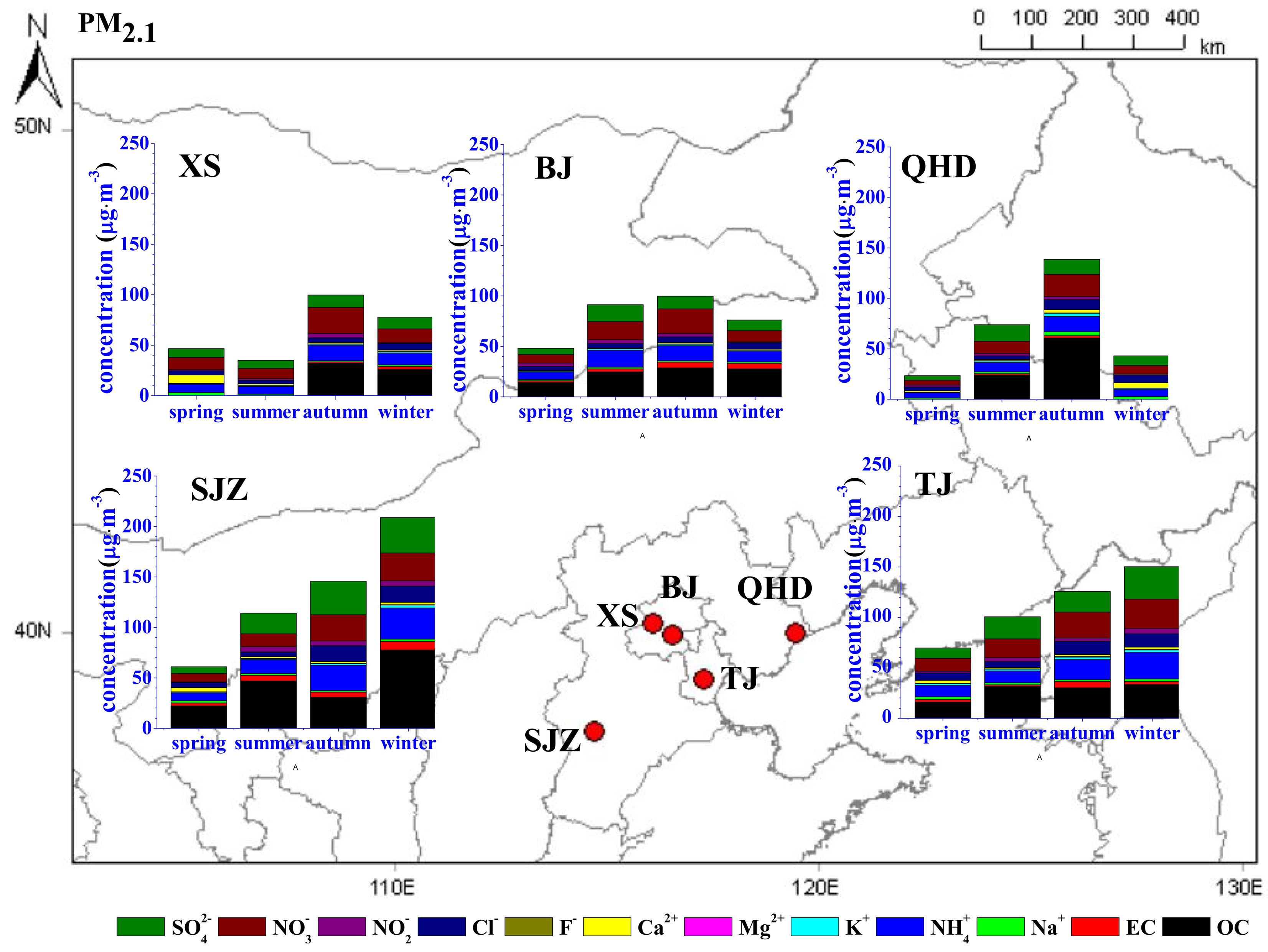

Fig. 1. Distributions of five stations and compositions of WSIs and carbonaceous aerosol in $PM_{2.1}$ in four seasons.

As shown in Fig.2, the correlation coefficient r, between reconstructed visibility and measured visibility, reached 0.91 (Beijing) and 0.80 (Tianjin). The reconstructed visibility was larger than the measured visibility on most rainy days, which was associated with the lower light extinction factor under the rain wash.

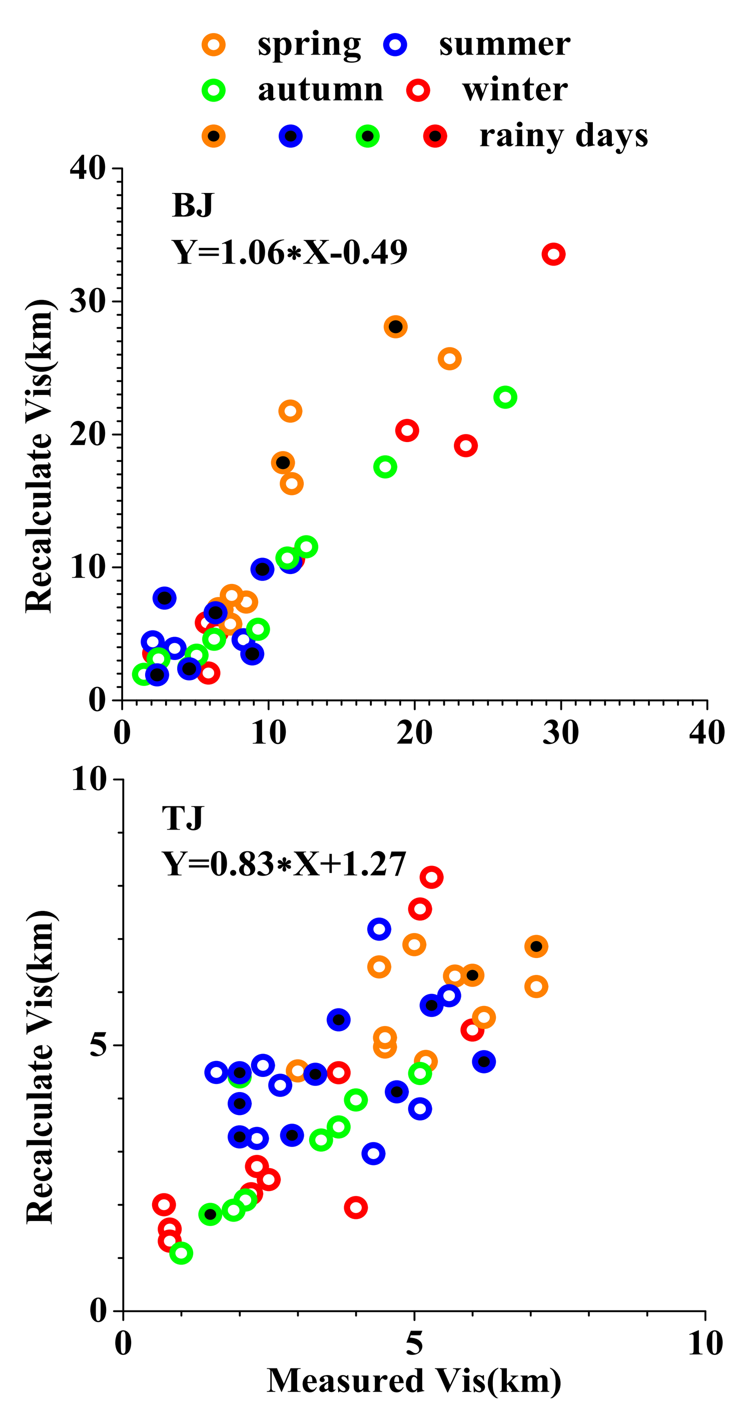

Fig. 2. Correlation between reconstructed and measured visibility in four seasons in Beijing and Tianjin. The solid circles represent a rainy day.

As shown in Fig. 3, NH_4^+, NO_3^- and SO_4^{2-} mainly existed in the fine size in winter in BJ (73.5, 80.7, 78.0% on PD and 63.3, 79.4, 72.5% on AD) , which show that the secondary inorganic water-soluble ions were mainly concentrated in the fine size. OC, EC and SOC was mainly existed in the fine size in winter in BJ(70.5, 53.8, 80.6% on PD and 62.7, 53.7, 66.3% on AD), which also had a peak in the coarse size (9.0-10.0μm) on both PD and AD.

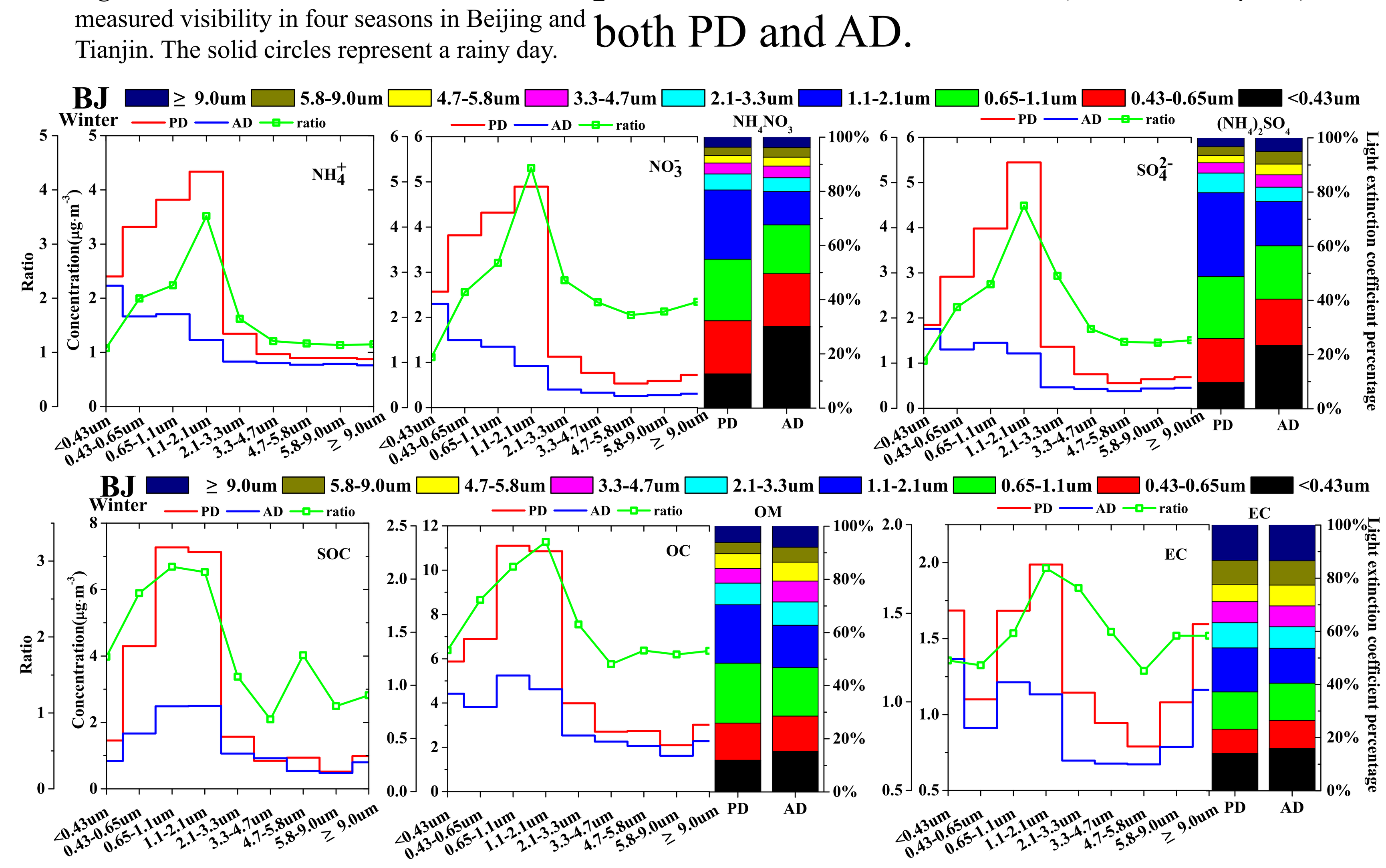

Fig. 3. Average mass size distribution of NH_4^+, NO_3^-, SO_4^{2-}, OC, EC and SOC, their mass ratio of PD to AD within different size ranges, and size-segregated light extinction coefficients fraction of NH_4NO_3, $(NH_4)_2SO_4$, OM and EC in winter in Beijing.

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